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Valuing Reductions in Risks A Review of the Empirical Estimates - Summary

Energy and Resource Consultants, Inc.
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Valuing Reductions in Risks:

A Review of the Empirical Estimates — — Summary

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16. Abstract (Limit: 200 words) This document summarizes the empirical estimates of the values associated with changes in health risks. Previous reviews have not included both the range of estimates found by each study and the rationale for selecting one estimate as better than another for policy questions. The qualifications presented by the study authors, along with their estimates and the context in which they are estimated, are important for interpreting the policy usefulness of these numbers. Prior reviews give these considerations a cursory treatment and when the estimates actually app ear in policy assessments, the qualifications tend to disappear entirely. The result often has been inappropriate application of the estimates and, even where applied properly, the level of confidence policy makers should have in the numbers generally has been left unstated. The main report compiles the available empirical estimates and documentation in one reference source, presents a critical discussion of the estimates, and evaluates their usefulness in environmental policy assessment. The primary difference between the two versions is that this summary does not contain a detailed technical discussion.

Those desiring more detail are referred to the main report: Valuing Reductions in Risk: A Review of the Empirical Estimates. #EPA/230-05-83-002.

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SUMMARY VERSION

of

VALUING REDUCTIONS IN RISKS: A REVIEW OF THE EMPIRICAL ESTIMATES

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U.S. Environmental Protection Agency

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Responsibility for remaining errors and omissions rests, of course, with the authors.

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CHAPTER 1.0

INTRODUCTION TO THE SUMMARY VERSION

Many of the programs and policies that are under development by the U. S. Environmental Protection Agency will influence the level of health risks faced by individuals. Executive Order 12291 requires that the potential benefits of a major regulation be shown to outweigh the potential costs before it is adopted. Assessing the benefits and costs of changes in health risks associated with a regulatory action poses many difficult problems.

This document is a summary of a report reviewing empirical estimates of the values associated with changes in health risks.* The primary difference between the two versions is that this summary does not contain a detailed technical discussion of each study reviewed. The emphasis is on presenting overviews of the research and the conclusions drawn by the review. In many cases, only a brief discussion of the different studies is incorporated here. Those desiring more detail are referred to the main report.

Previous reviews have not included both the range of estimates found by each study and the rationale for selecting one estimate as better than another for policy questions.** The qualifications presented by study authors, along with their estimates and the context in which they are estimated, are important for interpreting the policy usefulness of these numbers. Most prior reviews give these considerations a cursory treatment and when the estimates actually appear in policy assessments, the qualifications tend to disappear entirely. The result often has been inappropriate application of the estimates and, even where applied properly, the level of confidence policy makers should have in the numbers generally has been left unstated. The purpose of the main report is to compile the available empirical estimates and documentation in one reference source, present a critical discussion of the estimates, and evaluate their usefulness in environmental policy assessment. Many questions are raised for which adequate empirical studies are not available, but which point to useful avenues for future research.

The project focused only on willingness-to-pay (WTP) and willingness-to-accept-compensation (WTA) estimates for valuing changes in risks. Other valuation approaches have been used including estimates of future earnings that would be lost due to an increase in deaths or illness and estimates of medical expenses associated with an increase in illness and death. Although providing useful benchmarks, these approaches do not provide estimates of the benefits to the individual of reducing or preventing health risks because they do not reflect the change in utility, or well-being, that would result from the change in risk of illness or death.*** WTP and WTA measures reflect how much of other goods and services the individual is willing to give up in order to obtain a reduction or prevent an increase in health risks. This, therefore, gives a dollar measure of the change in well-being that the individual has or expects to experience. Summing this measure of individual benefits across all affected individuals can provide one component of a benefit-cost analysis.

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* The main report is Valuing Reductions in Risk: A Review of the Empirical Estimates. #EPA/230-05-83-002.

** Recent reviews include Bailey (1979), Butcher (1981) and Blomquist (1982).

*** Butcher (1981) and Bailey (1979) discuss this in more detail.

Risks of fatalities, rather than of nonfatal injuries or illnesses, are emphasized in this review. This should not be construed as implying that risks of morbidity are irrelevant for environmental policy questions, because they are very important. This emphasis merely reflects the fact that most empirical estimates of the value of life and safety have used mortality data. The many facets of morbidity have not made it conducive to empirical work. Individuals suffering from an illness differ in the severity of the symptoms, the length of the illness, and whether it is an acute or chronic malady. On the other hand, mortality tends to be an unequivocal health measure.

We apologize in advance to any authors whose work may be relevant but omitted from this document. Simply reading all of the potentially relevant reserach work would have exhausted the project funds. A common response of reviewers to the draft version of the report was to list 10 to 15 potentially relevant articles that we had not incorporated. Of course, it was not possible to include all of the helpful suggestions. We feel that we have included the major empirical results, but work on related theoretic issues was included on a very selective basis. A major line of research that was omitted concerns the relationship between the "value of life" and human capital as expressed largely by one's lifetime earnings and activities. Selected contributions include Usher (1973), Conley (1976), Jones-Lee (1978 and 1980), Linnerooth (1979) and Arthur (1981). The focus of this work has been on identifying when a person's human capital, based on lifetime earnings and consumption, can be viewed as a lower bound to the value placed on his/her life on purely theoretical grounds. Mishan (1982) points out that the conclusions from these models remain unvalidated until we have direct estimates of the "value of a life." Once the estimates are obtained, these models become superfluous for policy making. In any event, since these articles did not present empirical results and since the large amount of work on this topic could not be easily reviewed or condensed, they were reluctantly excluded from this document.

Throughout this report, the results of the different studies are compared by reference to the estimated value of life or value per life saved. The reader should be aware that this is not meant to be thought of as an amount of money that an individual would accept in exchange for his or her life. This is rather a way of comparing valuations for small reductions in risks that affect a large number of people. For example, say a certain environmental policy decision will reduce the risk of death from exposure to a given toxic substance from 1 out of 100,000 to 1 out of 200,000 for a total of 1,000,000 people. Each individual's probability of death from this cause will be reduced from 10×10^{-6} to 5×10^{-6}, a change of 5×10^{-6}. If every individual is willing to pay $10 for this reduction in the probability of his or her death, then the willingness to pay per life saved is

$$\$10/.000005 = \$2,000,000$$

An alternative derivation of this "value of life" is to look at the number of lives saved. The number of deaths out of the 1,000,000 people affected would be reduced from 10 to 5. For these five lives each individual in the group would be willing to pay $10. Thus the total value per life saved would be:

$$\$10 \times 1,000,000/5 = \$2,000,000.$$

The studies reviewed in this report are grouped into three categories. Chapter 2 covers hedonic wage-risk studies that look at tradeoffs between on-the-job risks and wages. Chapter 3 includes consumer market studies that examine consumption and activity choices that people make that affect their safety. Chapter 4 covers contingent market studies that use surveys that ask people how much they value increases in safety or improvements in health. Chapter 5 discusses estimation issues that are of concern for policy questions related to environmental health and safety, but that have not been addressed in these empirical studies. Chapter 6 summarizes the conclusions of the report and provides suggestions for future research.

CHAPTER 2.0

RISK VALUATION USING WAGE STUDIES

This section examines empirical estimates of the value of life and safety that have been based on observations of transactions that take place in the labor market. These studies have found a consistently positive and statistically significant wage premium that is attributed to risks of injury on the job.

2.1 Hedonic Wage-Risk Studies — Introductory Discussion

These studies are based on hedonic price theory which views a market good as a bundle of attributes that can occur in various combinations and quantities. The price that the consumer is willing to pay for such a good is a reflection of the sum of the utility expected to be derived from the attributes. The labor market can be viewed from this perspective. The worker supplies his labor for a job that can be described by a set of job characteristics, or attributes, in exchange for a wage. These job characteristics include such things as job safety, type of work, location and physical environment. At the same time, the employer is willing to offer a certain wage in exchange for having this job done. This interaction between the employers and the workers maps out a set of market equilibrium wages that are paid or accepted for specific jobs reflecting the associated job characteristics. In the case of risks of accidents and illnesses resulting from work activites, we can expect a tradeoff between the wage rates that workers will accept and the risks they expect to encounter. Also, there is a tradeoff between the measures an employer is willing to take to make the job safer and the wage he must pay to attract workers. If wages are positively related to job risks, then the employer can implement additional safety measures in return for a lower wage-risk premium required by workers. In theory, the employer will undertake safety improvements up to the point where the marginal cost of increasing job safety equals the marginal reduction in wage cost resulting from a lower risk premium being demanded by workers. The worker's position will be influenced by his skills in protecting himself, his aversion to risk and other socio-economic characteristics. The employer's position will be influenced by his production technology and the costs and benefits to him of providing increased safety on this particular job.

This market equilibrium between workers and employers establishes the risk premium paid to workers. It is important to recognize that the wage-risk studies do not estimate an individual's wage-risk indifference (i.e., tradeoff) curve ; instead the market clearing wage-risk function is estimated. This market equilibrium, or hedonic wage-risk function, represents one point on each worker's indifference curve. The only data point available is the wage accepted and the associated level of risk for each individual Other points on each worker's indifference curve are not known. As a result, the hedonic wage-risk curve must be carefully interpreted.

According to conventional econmic theory, an individual's wage-risk indifference curve would be convex (see Curves A and B in Figure 2-1), since most individuals would require compensation at an increasing rate to entice them to accept greater levels of risk. However, the assumption of convexity for individual's wage-risk curves says nothing about the shape of market clearing hedonic wage-risk curve. In fact, several authors have argued that workers who pace a lower value on incurring risks (i.e., require a lower wage-risk premium) will, through the market process, gravitate to the more risky jobs. If true, this could result in the concave hedonic wage-risk curve shown in Figure 2-1.

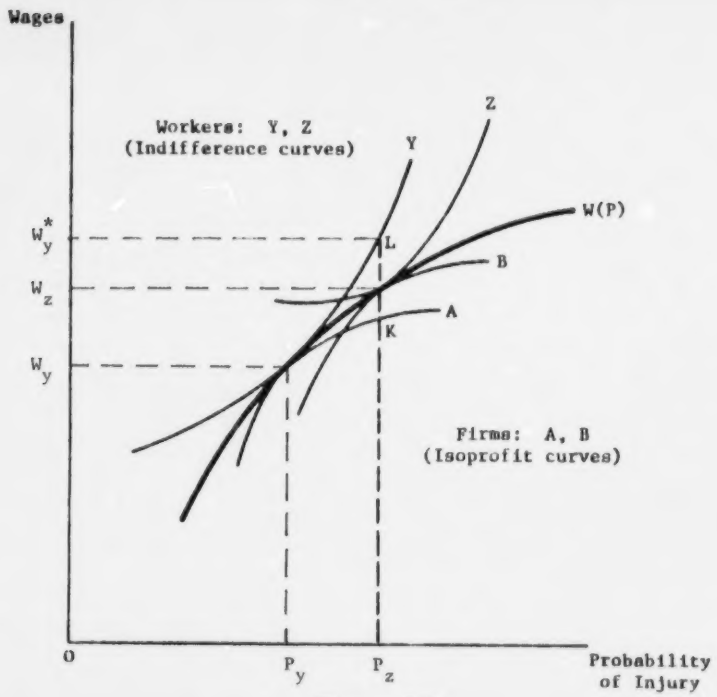

Figure 2.1
Market Equilibrium

Source: Butcher 1981

Hedonic Estimation Assumptions

The estimation procedure used to identify the tradeoff between wages and job characteristics is to take wages as a function of job characteristics and see how changes in job risks affect market determined wages. Market equilibrium will occur where each worker is maximizing his utility with the wage-risk tradeoff that he accepts; therefore, the point at which he is observed will reflect the marginal valuation he would put on a marginal change in risk, holding all else constant. In order for this marginal valuation of risk to be reflected in market conditions as has been described, certain assumptions must be met. Two or the most problematic are (1) that the labor market operates freely and is in equilibrium, and (2) that workers are aware of the risks associated with different jobs that they might consider.

If the first assumption is violated, the estimated valuation can be biased. If, for example, a universal improvement in safety equipment has occurred and wage markets have not yet adjusted, observed risk premiums may be biased upward because they are still reflecting the higher level of risk. Slow adjustments will not introduce bias if changes in safety have occurred randomly and in both directions—better equipment introduced in one place and a more dangerous procedure in another. These reviewers are not aware of any empirical evidence concerning the speed and nature of these kinds of labor market adjustments.

Union bargaining power may also push risk premiums higher than they would be under competitive equilibrium conditions. Several authors (Olson, 1981; Thaler and Rosen, 1975; V. K. Smith, 1982) have found a positive and statistically significant interaction between union membership and wage-risk premiums. Union members are observed to receive greater compensation for incurring risk than nonunion workers. A variety of explanations could account for this, each requiring empirical verification along some other avenue. Whatever the correct explana-

tion, it is doubtful whether, based on this evidence, the EPA would want to conclude that union workers are more risk averse than nonunion workers or that the benefits of protecting union workers are greater than protecting nonunion workers.

The assumption that workers are aware of the risks associated with different jobs is necessary in order for observed wage-risk premiums to be an accurate reflection of the amount of compensation that would be required to induce the individual to accept such a risk. Misperceptions that are random will increase the standard errors of the estimated wage-risk premiums but the estimate will be biased only if there is some systematic pattern in the misperceptions. Very little is known about the factors that may influence a person's perceptions of risk. Lichtenstein et al. (1978) found that there was some systematic error in what people thought to be the frequency of lethal events. Some empirical work in the form of surveys concerning perceived injury rates could be very helpful in terms of establishing the validity of wage-risk studies for quantifying risk premiums.

2.2 Summary Review of the Wage-Risk Studies

Eight wage-risk studies were reviewed. All of them use some variation of the hedonic framework that was introduced above. The authors of these studies were aware of the potential policy applications of their results, but the focus of these studies has been on testing whether the labor market functions as is theorized. In this sense, they are concerned more with accurate characterizations of the labor market than with the applicability of their estimates to policy questions.

A description and summary of each study can be found in Table 2-1. Except for Dillingham (1979), each study used data on job risks from one of two sources--the Bureau of Labor Statistics (BLS) or a survey conducted by the Society of Actuaries. The appropriateness of the two data sets has been one area of contention in the wage-risk literature. The BLS data provide average injury rates by industry. The use of industry averages introduces measurement error because job risks are not uniform across occupations within an industry. For example, clerical workers and heavy machinery operators in the same industry will face very different job risks. Most studies have attempted to reduce potential measurement errors by including dummy variables to distinguish beween different occupations within an industry. For example, R. Smith (1974 and 1976) used dummy variables for eight occupation classifications: professional worker, manager, clerical, craftsmen, operatives, service workers, laborers, and part-time workers.

The most often cited value-of-life estimates are those obtained by Thaler and Rosen (1975). They were the first to use the 1967 occupation survey conducted by the Society of Actuaries. This survey provides data on actual deaths associated with selected hazardous occupations. To isolate occupational fatalites from these data on total fatalities, Thaler and Rosen subtracted the age adjusted expected deaths for the population. The remainder is assumed to represent deaths associated with the occupation.

Thaler and Rosen claimed that the use of this occupational risk data is superior to the BLS injury indices by industry used by R. Smith (1974). They admitted that some measurement errors exist in their data set since the occupational classifications are still quite broad, but they asserted that the degree of measurement error in their risk estimates is perhaps as much as an order of magnitude smaller than with the BLS data.

While their occupational risk data have some desirable attributes, the particular data set used by Thaler and Rosen contains some potential problems. Lipsey (1975) pointed out that their risk data actually measure something other than occupational risk. The risk they are measuring is the extra risk to the insurance company of insuring those who are in a particular occupation. This insurance risk will encompass both true occupational risk and risk associated with personal characteristics. Using Lipsey's example, people attracted to bartending may have personal habits or characteristics which increase their insurable risk independent

Table 2-1

Hedonic Wage-Risk Studies Summary Table

Study	Variables & Data Sources	Unique Aspects	Estimation Approach	Results 1982 Dollars	Comments
R. Smith (1974)	o Three risk variables were used: risks of death, permanent impairment, temporary disability. Injury rates by industry were obtained from from the Bureau of Labor Statistics for 1966 and 1967. o Individuals' data on wages, union membership, education, worker class, experience, age, occupation, past health problems, geographic region and other demographic variables were obtained from the 1967 Survey of Economic Opportunity, U.S. Census.	This was the first study to use occupational wage and risk data to try and estimate a wage-risk premium. The actual goal of study was to estimate what "injury fine" would be necessary to encourage firms to reduce injuries. The wage-risk relationship was one component of the model.	Two specifications were examined. Both regressed the natural log of wages as a function of job risks and other socioeconomic variables. One equation incorporated dummy variables for the following industry groups: construction, manufacturing, personal services, business services and wholesale trade. Both specifications incorporated regional dummy variables.	The two specifications showed substantially different results. The addition of the industry dummy variables reduced the estimated value of a statistical life from $13.2 million to $7.5 million. In the equation without the industry dummy variables, both fatal and nonfatal risks were significant variables in explaining wages. When the industry dummies were included, the fatal risk variable was significant and nonfatal risks were not significant.	o The large t-values for the industry dummy variables indicated that there are important factors which influence wages and vary across industries, but were omitted from the equation. o The mixed findings for the significance of nonfatal risks indicates that wage-risk models may not be useful for estimating the willingness to accept compensation for risks that are, at least, partially compensated ex post through insurance and workman's compensation. o The assumed wage-risk functional form was constrained to be convex.
Thaler and Rosen (1975)	o Risks of death for 36 hazardous occupations were obtained from the 1967 Occupation Survey conducted by the Society of Actuaries. o Wage data and other characteristics of individuals were obtained from the 1967 Survey of Economic Opportunity, U.S. Census.	Differed from R. Smith (1974) in that risks by occupation rather than risks by industry were used. Thaler and Rosen claimed that this reduced measurement error in the risk data since risks will vary across different occupations within an industry.	Linear and semilog linear equations were estimated with wage rates as a function of job risks and other characteristics of the occupation and individual. Selected risk/socio-economic interaction terms were included in several equations.	Of the eight equations estimated by Thaler and Rosen, four found a risk variable to be significant at the 90% confidence interval. Value of life estimates ranged from $390,000 to $746,000 for the equations without interaction terms. The equations with interaction terms found much lower value of life estimates, but the precision of the estimates was also much lower.	The risk data used are not true occupational risks. The risk they examined is the extra risk to the insurance company of insuring individuals who are in a particular occupation. This risk will include both occupational risks and risks associated with personal characteristics. This could explain some surprises in their risk data. For example, the risks of death associated with being a waiter were twice that of a policeman and three times that of a fireman. The potential inappropriateness of the risk data raises some concern regarding the soundness of the results.

Table 2-1

Hedonic Wage-Risk Studies Summary Table

(continued)

Study	Variables & Data Sources	Unique Aspects	Estimation Approach	Results 1982 Dollars	Comments
R. Smith (1976)	o The risk data were obtained from the 1970 Bureau of Labor Statistics injury rates. o The risk data were matched with wage data and characteristics for individuals from the 1973 Survey of Economic Opportunity, U.S. Census.	The large difference between the Smith (1974) and the Thaler and Rosen (1975) results motivated this study. Smith only looked at workers in manufacturing industries to reduce potential biases in the measured risks and from omitted variables.	A semilog linear specification was used. Two samples were used -- all workers in manufacturing and workers on an hourly wage.	The value-of-life estimates were consistent across the two samples: $3.2 million for the all manufacturing workers sample and $3.4 million for the sample consisting of only hourly workers.	Using data from different years and a more restricted sample of workers, R. Smith again found value-of-life estimates well in excess of the Thaler and Rosen estimates, although they were lower than his 1974 study results.
Viscusi (1978b)	o Like R. Smith (1974) Viscusi used risk data by industry from the Bureau of Labor Statistics. o A different source of wage and socioeconomic data was used -- the 1969-70 Survey of Working Conditions compiled by the University of Michigan.	Viscusi used a set of occupation and socioeconomic data that contains variables indicating whether the individuals assessed their job as dangerous as well as a number of descriptive job characteristics that could influence wages.	Used linear and semilog linear specifications. Also ran regressions on all workers and on a sample limited to workers who perceived their job as dangerous.	The fatal risk variable was consistently significant. Segmenting the sample into only workers who perceived their jobs as dangerous had only a small influence on the estimates. Value-of-life estimates were similar to R. Smith (1976), i.e., approximately $3 to $4 million.	This study addressed one of the criticisms of R. Smith's use of the BLS data. Namely, that the use of industry average data introduces measurement errors since the job risks will vary substantially across occupations. The self-assessed job danger variable allowed Viscusi to incorporate more information and look only at occupations perceived as risky.
Dillingham (1979)	o Risk data were compiled from the New York State Workman's Compensation Board. o Wage, employment and socioeconomic data came from the 1970 Census.	This is the only study to use actual occupational risk data, rather than the BLS industry-wide averages or the actuarial insurance data used by Thaler and Rosen.	All equations were semilog specifications. A number of specifications were used. Regressions were run on a sample comprised of all male workers and a sample limited to male blue-collar workers.	No significant relationship was found between job risks and wages for the sample comprised of all workers. The sample of blue-collar workers showed a consistently significant relationship between risks and wages. The estimated value-of-life for the sample of blue-collar workers was approximately $400,000.	o The Dillingham results are similar to Thaler and Rosen's estimates, and were an order of magnitude smaller than R. Smith's or Viscusi's estimates. o The lack of a significant relationship between wages and risks for the all-worker sample is not surprising due to the low average risk level for that sample.

Table 2-1

Hedonic Wage-Risk Studies Summary Table

(concluded)

Study	Variables & Data Sources	Unique Aspects	Estimation Approach	Results 1982 Dollars	Comments
Olson (1981)	o Used essentially the same data set as R. Smith (1976). o Risk data by industry for 1973 from BLS o Wage and socioeconomic data came from the 1973 Survey of Economic Opportunity, U.S. Census.	This study relaxed the restrictions placed on the functional form of the wage-risk equation to allow for concave, as well as linear and convex (semilog), functions.	The estimated equations had the risk variable entered linearly and as a squared term to allow for the wage-risk tradeoff function to be either concave or convex.	Olson found a significant relationship between risks and wages. The squared risk variable was significant at the 99% confidence level. The negative sign on the squared risk variable indicated that the hedonic wage-risk locus is concave. The value-of-life estimate was $7.0 million.	This is the only study that allowed for a concave hedonic wage-risk function. All other studies constrained the function to be linear or convex. Theory indicates that a concave function may be appropriate and this is supported by Olson's findings.
V.K. Smith (1982)	o Risk data were 1975 industry injury rates from the BLS. o Wage and socioeconomic data were obtained from the 1978 Current Population Survey, U.S. Census. o The socioeconomic data were augmented by location attributes such as cost of living and other factors that could influence welfare and induce workers to accept different wages.	This study made two important contributions — wages were adjusted for cost of living at different locations and amenities available at the location were considered. Locational amenities such as climate, pollution, activities, etc. have been found to influence wages.	V.K. Smith only considered semilog specifications. Equations for males and females, males only and females only, were estimated.	A significant relationship between risks and wages was found for all samples. Since the risk variable was all injuries rather than only fatal risks, a value of life must be inferred indirectly. The estimate of a value-of-life was calculated to be $1.0 million.	o The use of wages adjusted by cost of living was a significant improvement. o The use of a semilog specification which constrained the wage-risk function to be convex could bias the estimate in light of Olson's results. o The implied value-of-life estimate is uncertain because fatal and nonfatal risks were not separated.
Arnould and Nichols (1983)	o The authors use the same data as Thaler and Rosen (1975) augmented by data on workman's compensation by occupation.	Attempts to incorporate the influence of workmen's compensation on wage-risk premiums. The hypothesis is that the failure to account for employer paid insurance biases the wage-risk premium downwards.	Linear and semilog functional forms were considered.	The addition of a workman's compensation variable to the Thaler and Rosen model increased the estimated value-of-life modestly, i.e., by 12%.	The use of risk data compiled by the Society of Actuaries is subject to the same problems as discussed in the comments on Thaler and Rosen.

of their occupation. On the other hand, people who work as policemen or firemen may be in better physical condition thereby reducing the incidence of illnesses or accidents. These personal characteristics could cause some of the occupations to have unexpectedly high fatality rates. For example, elevator operators, bartenders, and waiters were found to have higher death rates than policemen or firemen. If these higher rates are caused by personal characteristics that are attached to the individual rather than associated with the job, there will be no positive compensating wage differential. In fact, these characteristics could have the opposite effect, i.e., result in lower wages for these occupations. Having individuals as employees who are more likely to incur injuries increases the cost of doing business. This would result in lower productivity and, therefore, lower wages being offered to these individuals. The Society of Actuaries data used by Thaler and Rosen may have reduced one source of measurement error only to add another source of measurement error of an unknown magnitude.

Even if the Actuaries' occupational risk data were entirely accurate, it is questionable that it would match the perceptions of individuals in the labor market who are negotiating their wage-risk premiums. The ranking of occupations by risk does not conform to usual expectations. One of the assumptions of the hedonic technique is that the participants have accurate information regarding the risk characteristics of the job.

In conclusion, both data sets suffer from certain problems. As long as these measurement errors vary randomly across industries and occupations, the estimated wage-risk premiums will be unbiased. The only effect will be to increase the estimated standard errors which makes it more difficult to obtain statistically significant results. If one had to select one data set as better, the BLS data seems preferable since it measures only job related injuries.

2.3 Summary of Estimates from the Hedonic Wage Studies

These studies often conclude that there is substantial support for the hypothesis that wage differentials for job hazards do exist. The stated reason is that virtually all of the studies have found job risks to be significant and positively related to wages. Still, it is important to consider how confident a policymaker can be in using the numerical results from these studies. The establishment of causality is always difficult in econometric studies and there exist several potential confounding influences in these wage studies. This section will summarize the empirical estimates and, in the context of these estimates, some of the controversial issues will be discussed.

It is important to understand that a perfect empirical study can never be conducted and that even with weaknesses in the data or techniques, important insights may be generated. On the other hand, it would be a mistake not to recognize these shortcomings since they are important in the proper interpretation and application of the results.

A summary of the empirical estimates is presented in Table 2-2. Where studies considered more than one model specification or segmented the sample, multiple estimates are reported. A judgemental "best" estimate is also presented that represents either the author's recommendation or a guess by these reviewers based on judgement and information presented in the study.

The value-of-life estimates tend to cluster into two ranges—a $400,000 to $650,000 and a $4,000,000 to $7,500,000. These estimates differ by roughly an order of magnitude. The studies that use risk data for occupations compiled by the Society of Actuaries (Thaler and Rosen, 1975; and Arnould and Nichols, 1983) found estimates of the value for reductions in risk in the low range, while studies using BLS data on risks by industries tended to

Table 2-2

Estimates of the Marginal Willingness to Pay for Reductions in Risks (expressed in May 1982 dollars)[a]

	Study	Mean Risk Level for the Sample[b]	Value Per Statistical Life: All Estimates[c]	Value Per Statistical Life: Judgemental Best Estimates[d]
1.	R. Smith (1974)	1.0 to 1.5	$ 7.5 x 10^6 13.2 x 10^6	$ 7.5 x 10^6
2.	Thaler and Rosen (1975) a. Without risk interaction terms[e]	11.0	3.90 x 10^5 5.05 x 10^5 5.42 x 10^5 7.46 x 10^5	5.7 x 10^5
2.	Thaler and Rosen (1975) b. With risk interaction terms[f]	11.0	.14 x 10^5 1.99 x 10^5 2.75 x 10^5 3.36 x 10^5	
3.	R. Smith (1976)	1.0 to 1.5	3.22 x 10^6 3.44 x 10^6	3.3 x 10^6
4.	S. K. Viscusi (1978b)	1.2	1.46 x 10^6 2.23 x 10^6 2.66 x 10^6 3.44 x 10^6 3.95 x 10^6 4.21 x 10^6 4.38 x 10^6	3.9 x 10^6
5.	A. Dillingham (1979)	1.7	3.4 x 10^5 4.0 x 10^5 4.1 x 10^5 4.3 x 10^5 11.0 x 10^5	4.0 x 10^5
6.	C. Olson (1981)	1.0	7.1 x 10^6	7.1 x 10^6
7.	V. K. Smith (1982)	3.0[g]	7.3 x 10^5[h] to 20.7 x 10^5	1.0 x 10^6
8.	Arnould and Nichols (1983)	11.0	6.40 x 10^5	6.40 x 10^5

Notes to Table 2-2

a Adjustments to 1982 dollars were made by using the consumer price indices for all items published by Council on Economic Advisors, Economic Indicators, December 1982.

b The risk level is expressed in annual deaths per 10,000 workers. The value should be viewed as an approximate figure since many of the studies reported risks in different units requiring transformation to common units.

c The multiple estimates are derived from the different model specifications examined. It was felt that presenting estimates from all the specifications is better than simply showing the range of estimates since one outlier can distort the range.

d The judgemental "best" estimate represents either the author's recommendation or a guess by these reviewers based on judgement and the information provided by the authors of each study.

e These estimates are from Thaler and Rosen (1975) equations that did not include interaction terms between risk and other variables.

f From specifications including interactions variables between risk and nonrisk variables.

g Calculated by assuming that .4 percent of all injuries are fatal. This is ratio for the BLS injury statistics is reported by Viscusi (1978b, p. 365).

h Calculated assuming the risk premium for risks of fatal injuries ranged from 33 percent to 100 percent of the premium associated with all risks.

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estimate considerably higher values. One explanation commonly advanced to explain the differences in these estimates is that the fatality rates contained in the Society of Actuaries data are for high risk occupations. The mean annual risk of death in the occupations examined by Thaler and Rosen (1975) is approximately 11.0×10^{-4}, where the mean annual probability of a fatal accident in data obtained from BLS statistics is close to an order of magnitude lower (1×10^{-4} to 1.5×10^{-4}). Olson (1981), R. Smith (1979), Viscusi, (1978b) and Blomquist (1981) argue that workers who place a lower value on safety are likely to be attracted to jobs with higher risks. In other words, workers who are least risk averse will be employed by these high risk jobs and estimates of the willingness to pay for marginal reductions in risk will be lower for these workers than for the average worker.

The implication of this hypothesis is that the hedonic wage-risk locus is concave. This implies that wage premiums increase, but at a decreasing rate, as job risks increase. One inconsistency in the hedonic wage-risk studies is that while most authors appeal to the hypothesis of a concave wage-risk locus as one explanation of the differences between the estimates, in the empirical work all the studies (with the exception of Olson, 1981) constrained the wage-risk locus to be either convex, through the use of a semi-log specification, or linear. Only Olson (1981) allowed for the existence of a concave wage-risk locus. He incorporated a squared risk term in the wage equation and found the coefficient on the squared term to be negative and highly significant indicating that the function may, indeed, be concave. Constraining the hedonic wage-risk locus to be convex when it may actually be concave introduces the possibility of unknown biases in the estimated coefficient on the risk variable. Using essentially the same data as R. Smith (1976), Olson (1981) found the inclusion of the squared risk variable resulted in substantially different estimates of the value of life. The Olson (1981) results indicate that the linear or semilog model used by the other studies will bias the value of life estimates either upward or

downward depending on the risk level at which the value of life is estimated.

The estimates from Dillingham (1979) and V. K. Smith (1982) further confound the issue. The Dillingham study used a different occupational risk data set and the V. K. Smith study utilized a more detailed model specification. The mean job risk levels for the workers in their samples are considerably lower than in the Thaler and Rosen sample, but the estimated values of life are closer to the Thaler and Rosen estimates.

2.4 Methodological Issues in the Wage-Risk Approach: What Confidence Can Policy Makers have in the Estimated Wage-Risk Relationship?

One of the most often cited factors supporting the existence of wage-risk differentials is the consistent finding of risk as a positive and significant explanatory variable in wage models. Although persuasive evidence, this fact must be tempered by the realization that many of these studies used the same or very similar data sets and therefore cannot be viewed as independent verification of the existence of a risk related wage differential.

Summary of the Issues Raised by the Hedonic Studies

A number of theoretic and statistical issues are raised by the hedonic wage-risk studies that have been performed. Seven issues are identified below:

1. The potential for omitted variable bias: Are additional job characteristic variables and location specific variables necessary to control for other factors that influence wage differentials?

2. The potential biases in the job risk data sets.

3. Specification of the correct functional form (i.e., linear, semilog (convex), risk-nonrisk interaction variables, or squared risk variables (which allows the wage-risk locus to be convex or concave).

4. The paucity of appropriate risk data sets (i.e., most studies have used one of two available data sets).

5. The functioning of the labor market with respect to safety.

6. The separation of the estimated wage premiums into compensation for risks of fatal accidents and compensation for risks of nonfatal injuries.

7. Are wage rates adequate for the estimation of risk related differentials in total worker compensation which may include wage and nonwage components as well as worker compensation and life insurance?

The first issue--omitted variable bias--concerns whether the positive relationship between risks and wages found in these models might actually be due to a causal variable omitted from the model that is also strongly correlated with the measured job risk variable. If this were the case, then the job risk variable might not be a true causal variable but, instead, might be serving as a proxy for some variable omitted from the model. Even if there is a causal relationship between risks and the wage rate, omitting an important explanatory variable that is correlated with the risk variable will lead to a bias in the coefficient estimated for job risk.

The reason for being concerned about potential omitted variable bias is the limited inclusion of job characteristic variables other than job risks. The majority of the studies include risk as the principal variable distinguishing different jobs. A number of job characteristics other than risks could be hypothesized to affect wage differentials. These characteristics could include such things as repetitive work, physically tiring work, unpleasant working conditions (e.g., dirty, noisy, varying temperature and odors), and stressful conditions. If job risks are always associated with poor working amenities, it may not be possible to disentangle factors associated with daily working conditions and pure safety hazards. This is particularly relevant when considering the potential transferability of these willingness-to-pay esti-

mates to nonwork related risks that may not be associated as closely with these disamenities. In sum, given the circumstances and job characteristics of the risky jobs that have been considered in these studies, it is not clear that these wage differential estimates reflect only the effects of risks. One could easily see that working in a pleasant environment at a job with a 1 in 10,000 chance of a work related fatality could require a very different wage premium than working in a noisy, dirty environment with varying temperatures at a job also associated with the same 1 in 10,000 risk of death.

The second issue concerns the potential biases in the job risk data sets. One of two data sets have been used in all but one of the studies. Each data source has potential problems. The BLS data supply only average injury rates by industry, ignoring the substantial variation in accident rates for different occupations within an industry. The 1967 study by the Society of Actuaries of differential mortality rates across occupations does not distinguish between job related and nonjob related accidents. To the extent that the risk data from these two sources are biased or are correlated with important, but omitted, explanatory variables, the results of all of the studies will likely suffer from similar biases.

The third issue concerns the a priori specification of the wage function to be estimated. In spite of theoretic and empirical evidence that the hedonic wage-risk locus may be concave, all but one of the studies have constrained the function to be either linear or convex. If the correct function is concave over the relevant range of risks, then the estimated coefficients will be biased in an unknown direction.

A fourth issue is the paucity of data sets containing information on the risks of injury for different jobs. Ideally, the wage or earnings equation should be estimated with data on individual workers. Such data are available for income, occupation, age, education, and other characteristics of the individual worker (many studies have used U.S. Census or Current Population Surveys), but data for on-the-job risks are more difficult to obtain. In general, these have been taken from other sources and matched to the individual data. One would like to look at the significant coefficients obtained by each of the eight or nine studies as strong evidence for the existence of risk related wage differentials. Although persuasive, this evidence must be tempered with the understanding that the data sets used in these studies are not independent. Further, similar techniques using the different data sets tend to give divergent estimates.

A fifth consideration concerns whether the labor market operates efficiently with respect to wage rates and safety. The underlying assumptions are that workers act as if they accurately perceive the risks associated with different jobs and appropriately account for these risk differentials in their choice of job. An additional assumption is that the labor market is free of structural constraints that might prevent workers from changing jobs. Tests of these underlying model assumptions have been limited. This is particularly true for the assumption that all workers accurately perceive the risks associated with different jobs. Viscusi (1978a and 1978b) presented information on whether the workers in his sample considered their jobs dangerous. This dummy variable was positively correlated with the BLS data on industry injury rates, but certain anomalies were present. In particular, the fraction of workers in the most dangerous industries that rated their jobs as dangerous was less than the fraction of workers in lower risk jobs who considered their jobs dangerous.*

An interesting potential violation of the assumptions of an efficiently operating labor market with respect to safety would involve the unequal distribution of information on job risks across workers. This could result in some workers overestimating the risks associated with specific jobs, some workers underestimating the risks of

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* This might result from workers in riskier jobs being less risk averse and, therefore, judging their jobs as not dangerous.

specific jobs, and some workers with accurate perceptions of job risks. Even if this job risk information is randomly distributed across workers, a bias in the estimated risk coefficient can result. In a process somewhat similar to the market for lemons (see Varian, 1978, p. 232), workers who underestimate job risks will gravitate to the riskier jobs, while workers who overestimate job risks will tend to accept lower risk jobs. If this is true, the use of actual risk data in hedonic wage-risk models rather than the employed workers' perceived job risks will bias the estimated wage premium downward. This results from the firm having only to offer the wage premium necessary to attract the marginal worker.

The sixth issue concerns whether the wage premium can be separated into a premium associated with fatal risks and a premium for nonfatal risks. An ability to distinguish between these two willingness-to-pay values would improve the policy relevance of the estimates and the transferability of the estimates to nonwork related safety improvements. Some empirical data exist but the multicollinearity between the fatal and nonfatal accidents tends to confound the results. Many studies have used only fatal injuries with the explicit (or implicit) assumption that these are correlated with nonfatal injuries and can therefore represent both. Other studies have used as risk variables the frequency of nonfatal accidents, distinguishing in some cases between temporary and permanent disabilities, or the number of workdays lost. None of these measures is an exact measure of the risks of pain, inconvenience and decreased freedom of activity that would represent the loss of utility to the injured individual. Also, it is likely that worker's compensation will at least partially compensate workers for nonfatal accidents, thereby reducing the wage premium necessary to attract workers to industries with high risks of nonfatal injuries. Since most hedonic studies have neglected the role of worker's compensation, using wage differentials to estimate the willingness to pay to avoid nonfatal accidents will be biased downwards.

The seventh and final issue concerns whether the use of wage rates rather than total compensation (wage and nonwage) is adequate for the estimation of risk related wage differentials. The most obvious problem is that worker's compensation and other insurance benefits may compensate the worker for incurring risks, a compensation that will not show up in wages. Ignoring other nonwage benefits may distort the estimation of wage-risk premiums if such benefits have any tendency to vary with the level of risk to which the worker is exposed. Ideally, a measure of the total value of a worker's wage and nonwage compensation should be used in these estimations. The importance of this measurement error is not apparent from the studies completed to date.

Applicability of Wage-Risk Results for Environmental Policy Decisions

Even if the wage-risk tradeoff is an accurate description of behavior in the labor market it may or may not provide useful information for environmental policy decisions. EPA must make decisions concerning the expenditure of resources to improve or protect public health and safety. A useful input for these decisions would be how much such protection is valued by the public. Wage-risk studies may be able to provide such input in some circumstances, but several issues must first be addressed.

One concern is whether the nature of the risks involved on the job are comparable to those associated with a specific policy question. Individuals may not be concerned only with the probability of death, but the way which that death is likely to occur. The risk of falling twenty stories while cleaning windows may not be considered equivalent to the risk of a slow, painful death from cancer, even if the probabilities of each of these occurrences are equal. Since EPA is often concerned with nonfatal and fatal effects of pollutants that may be of a very different nature than on-the-job accidents, estimates of the value of life and safety from

wage-risk studies may not be transferable.*

Wage-risk studies examine the tradeoffs made between risks and income for a certain segment of the population. At best, this segment includes only members of the employed labor force, thus underrepresenting children, elderly, women and others. In practice, the studies often look at an even smaller segment of the population by sampling only male workers, full-time workers, or blue collar workers. If we expect significantly different valuations on life and safety across different population groups, the valuations estimated for one group cannot be extended for the general public or for other specific groups expected to be affected by a pollution control decision.
Again, empirical analysis is needed to determine the nature and extent of differences in valuations of life and safety across the population.

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* If more information were available concerning the differences in the way people value different risks, it would be possible to say that premiums for on-the-job risks represent an upper or lower bound. There is some evidence, for example, the involuntary risks are considered less tolerable than voluntary risks, but the evidence is as yet inconclusive. It would also be necessary to know how workers differ from nonworkers in the way they value risks.

CHAPTER 3.0
CONSUMER MARKET STUDIES

Individuals make tradeoffs in their lives between risks and benefits in the consumption of many goods and services. Studies of these choices may be able to reveal the implicit valuation that people are placing on these risks. This approach is based on the presumption that individuals will maximize utility by choosing to accept risks up to the point where the expected benefits of accepting these risks just equal the expected costs of the risk. If the benefits can be quantified, then the implicit valuation on the risk is revealed. Just as with the wage-risk studies, the validity of these kinds of estimates depends on people having accurate perceptions of the risks that alternative activities entail. Two types of risks have been examined in the three studies that were reviewed--risks of automobile accident fatalities and risks of residential fire injuries.* A summary of the three studies is presented in Table 3-1.

Dardis (1980) used information about how much people pay for smoke detectors to infer how much they are willing to pay to reduce the risk of fatal and nonfatal injuries due to residential fires. The price of the smoke detectors was used as a measure of willingness to pay for the increased safety they provide. This is accurate only for the marginal consumer. Other purchasers may have substantially higher willingness to pay than the market price, reflecting their consumer surplus.

Blomquist (1979) looked at the decrease in risk of fatal injury when a driver buckles his seat belt. The only cost of seat belt use he was able to quantify was the value of the time it takes. By ignoring the inconvenience and possible discomfort of wearing them he underestimated the willingness to pay for the increased safety that seat belt use provides. It is also questionable whether the time it takes to buckle and unbuckle seat belts is an important factor in whether or not they will be used.

Ghosh, Lees and Seal (1975) examined the trade off that people make in terms of time saved and increased risk in choosing a driving speed on the highway. Their calculations assumed that the only benefit of driving faster is the time it saves. To the extent that there are additional benefits of driving faster, their estimate of the benefit required for people to increase their risk of death is a lower bound.

Table 3-2 summarizes the value of life estimates that have resulted from these three consumer market studies. In each case, the estimate is based on assumptions that were made in the analysis and that may not be valid. In most cases the major assumptions tend toward an underestimate of the value of life. It is not surprising that the estimates are on the low side compared to many of the wage-risk study results.

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* A third type of risk is examined in Portney (1981). He suggests a methodology for estimating the value of reduced risks of mortality by examining premiums paid for homes in neighborhoods with lower air pollution and the resulting expected reduction in risk of death associated with the lower pollution level. This is an interesting approach but would be more complicated to apply than his illustration suggests. An observed air quality premium can only be interpreted as the willingness to pay of the household that has chosen to pay that premium. It would therefore be necessary to use the actual housing premium and air pollution level at which the household is observed in order to calculate the implied value of life. Portney points out the additional problems of separating aesthetic, morbidity and mortality components of the air quality premium.

Table 3-1

Consumer Market Studies Summary Table

Study	Risk	Unique Aspects	Data Sources	Estimation Approach/ Major Assumptions	Results 1982 Dollars	Comments
Dardis (1980)	Risks of fatal and nonfatal hospitalized injuries due to residential fires; changes in annual risks of death of 3.16×10^{-5} and annual risks of injury of 2.26×10^{-5} associated with use of smoke detectors.	Use of a market good which has the primary purpose of reducing risk of injuries and fatalities provided a good setting for observing actual behavior with respect to risks.	Risk data from National Fire Protection Association, National Fire Prevention Control Administration and U.S. Consumer Product Safety Commission.	Annualized price of smoke detectors was taken as a measure of willingness to pay for the reduction in risk of death and injury that they provide. Major Assumptions: Price reflects willingness to pay. Concern for property protection and transaction and installation costs are trivial with respect to smoke detector purchases.	Average value per life saved was $318,334 to $496,688 depending on the importance of fatal relative to nonfatal injuries.	Price will understate willingness to pay for some who have already purchased smoke detectors and will overstate it for those who have not.
Blomquist (1979)	Risks of fatalities in automobile accidents; changes in annual risks of death of 1.514×10^{-4} associated with seat belt use; average annual risks of death in automobile accidents are 3.027×10^{-4}.	Creative theoretical and statistical analysis was used to estimate an implied value of reducing risks from the observed decision of whether or not to use seat belts. Probit analysis was used to examine the seat belt use decision with income as one of the explanatory variables.	Risk data from Third International Congress on Auto Safety, Highway Safety Research Center, National Safety Council, Federal Highway Administration, Illinois Department of Transportation; seat belt use and individual data from Panel Study of Income Dynamics, 1972, University of Michigan.	Value of time spent buckling and unbuckling seat belts and an estimate of what benefits would have to be to induce all drivers to use seat belts were used to obtain an estimate of willingness to pay to reduce the risk of automobile accident fatalities. Major Assumptions: Value of time is an important consideration in the decision whether to use seat belts. Value of time is a fraction of the wage rate.	Average value per life saved was $540,747.	Even if the assumptions in the model are correct the estimation procedure provides only a lower bound estimate because the discomfort and inconvenience (other than time) costs of seat belt use were ignored and because the estimate is applicable only to those who do not currently use seat belts.
Ghash, Lees and Seal (1975)	Risks of fatalities in automobile accidents on British motorways; risk levels were not reported.	Made use of a believable tradeoff between time spent traveling and risks of fatalities.	Automobile accident and other motorway data from the Transport and Road Research Laboratory and journals including Traffic Engineering and Control and Accident Analysis and Prevention.	Tradeoff between travel speed and risk of accident was used to estimate the value of reducing risks of accidents using an estimate of the value of time. Major Assumptions: Value of time is equal to the wage rate. Saving time is the only significant benefit of driving faster.	Average value per life saved of $496,966.	The assumption that saving time is the only benefit of driving faster makes this estimate likely to be a lower bound.

TABLE 3-2
Summary of Value of Life Estimates from Consumer Behavior Studies

Study	Initial Risk Level	Increment of Risk Valued	Value Per Life 1982 Dollars	Nature of Risk Examined
Dardis (1976$)	8.77×10^{-5}	3.16×10^{-5}	$318,334 to $496,688	Residential fire fatalities
Blomquist (1972$)	3.027×10^{-4}	1.514×10^{-4}	$540,747	Automobile accident fatalities
Ghosh, Lees and Seal (1973$)	Not reported	Not reported	$496,966	Automobile accident fatalities on British motorways

The consumer market studies require several of the same assumptions and face several of the same problems as the wage-risk studies. They are based on the presumption that individuals make rational, well informed, utility maximizing choices with respect to risks. An important difference with consumer market studies is that we are looking at how much consumers will pay (or give up in terms of time and inconvenience) in order to reduce a particular risk. Wage-risk studies look at how much workers must be compensated in order to accept particular risks. Individuals' attitudes may be quite different in these two situations. Workers know that they are facing risks on the job that are earning profits for someone else. Since the benefits of accepting these risks accrue to someone else, the worker is likely to be unwilling to accept these risks without adequate compensation, and is likely to err on the side of cautiousness in his judgement about the magnitude of the risks he faces. With risks such as traffic accidents and residential fires, there may be more of a tendency for the individual to underestimate the risks with thoughts like it can't happen to me, or I'm a careful driver. In these cases the individual must take the trouble to buy a smoke detector, or fasten his seat belt, in order to reduce the risk. He must be convinced that the risk is troublesome enough for this to seem worthwhile.

As with wage-risk studies, consumer market studies face considerable data source limitations. Measures of risks that are available tend to be averages for large segments of the population. People will make choices based on the risks they perceive themselves to face, which may actually be quite different from the average risks. Risks of traffic accidents are not the same for all drivers in all parts of the country and neither are risks of fires the same for all residences. The benefits of accepting risks may be even more difficult to measure, as the studies by Blomquist (1979) and by Ghosh, Lees and Seal (1975) demonstrated.

These studies have done a reasonable job of developing credible models for the data with which they had to work, but data limitations and the uncertainty about the consistency of people's choices with respect to small changes in risks limit the general usefulness of this approach for environmental policy decisions, at least as far as these examples are concerned. The results of these studies do, however, confirm that people make tradeoffs between safety and other resources. They do not do everything they can in order to reduce a risk; the amount of resources that they expend in order to reduce risks is limited. Useful estimates for environmental policy purposes might be obtained through this approach if observable tradeoffs are being made for the kind of risks being considered, if the data are available and if behavior consistency can be confirmed.

CHAPTER 4.0
CONTINGENT MARKET APPROACHES

Contingent market approaches for valuing life and safety entail the use of surveys in which respondents are asked to directly or indirectly place dollar values on changes in risks of death or injury. They are called contingent market approaches because, for a good that is not normally traded on markets, a hypothetical market is posed to the respondent and he is asked what he would pay for the good, contingent upon the existence of such a market. This approach has received considerable attention recently for its potential in providing estimates of willingness to pay for environmental quality and other nonmarket goods. (See Brookshire et al., 1982, for an example of such an application and Rowe and Chestnut, 1982, for a detailed review of this technique as applied to the visibility impacts of air pollution.)

4.1 Background on Contingent Market Approaches

Contingent market approaches try to elicit, through the use of surveys, what tradeoffs people are willing to make between safety and income. Everyone wants better health and more safety, but the reality is that the amounts of time and money that people will expend in order to obtain better health and more safety are limited. In fact, people make tradeoffs all the time between increased risks on the one hand and monetary or other benefits on the other. The challenge of the survey approaches is to elicit accurately the valuations on safety that are behind these kinds of choices.

The most widely applied contingent market approach is the contingent bidding method. In this approach, as applied to the valuation of risks, respondents are given information on current and potential alternative levels of risks in a particular activity. They are also given hypothetical markets that describe how payments are to be made or received by the respondents for changes in this risk. Next, they are asked to bid their maximum willingness to pay (WTP) or minimum willingness to accept compensation (WTA) to prevent or incur the change in risk. Respondents may be asked to pay for reduced risk through increased taxes, increased product costs for safety, and increased time spent in travel and the like. The bids are usually obtained through one of three approaches--posing an open ended WTP or WTA question, asking the respondent to choose a value from a payment card with numerous alternative payment amounts listed, or using an iterative bidding procedure where the interviewer asks if the respondent is willing to pay (or accept) a specific amount and then continues to change the amount until a maximum WTP (or minimum WTA) is determined. These surveys usually also ask related questions on perceptions and attitudes as well as socioeconomic characteristics of the respondent in order to identify the underlying determinants of the bids and to check their reasonableness.

Another contingent market approach is the contingent ranking technique. With this procedure, respondents are asked to rank various sets of alternatives in order of preference. Each alternative would include a level of risk and a payment of some sort so that the rankings would reveal a valuation without the respondent having to give dollar estimates directly.

4.2 Summary of Contingent Market Studies

Five contingent market studies that have addressed questions of dollar valuations for changes in risks were reviewed. A summary description of these studies is presented in Table 4-1. For the most part, these studies are best interpreted as tests of the survey instruments and procedures because the samples are often nonrandom or too narrow to provide estimates applic-

Table 4-1

Contingent Market Studies Summary Table

Study	Risk	Unique Aspects	Hypothetical Scenario	Survey Procedures	Results 1982 Dollars	Comments
Acton (1973)	Risk of fatalities from heart attacks; U.S. average annual risk of heart attacks is one out of 100 and risk of fatality is two out of five -- total annual risk of death of 4×10^{-3}.	o Well defined scenario and believeable levels of risk. o Presentation of risk levels was complex but fairly clear.	Willingness to pay for emergency service that would reduce the risks of death once a heart attack occurred in the form of higher taxes.	o Random household sample of 32 individuals in the Boston area and two additional non-random samples of 14 each. o WTP questions concerned reductions in risks of death from current U.S. average and from hypothetically higher levels with total initial risk of death of 2×10^{-2}.	Implied value of $17,000 to $98,000 per life saved; the lower results from the elevated risk questions -- WTP did not increase in proportion to the increase in risk increment.	o Nonlinearities in results could be a function of question order and hypothetical scenario. o Two stage risk -- first of attack, then of death -- made the questions complex and may have affected the bids.
Jones-Lee (1976)	Airline accident fatalities.	Intended as an illustration of a possible survey procedure for obtaining estimates of values of reducing risks.	Hypothetical tradeoffs between airline prices and safety records.	o Non random sample of 31 academic and research workers. o Respondents were asked at what fare they would be indifferent between one airline with a given price and safety record and another airline with a different safety level.	Average implied value of $5,343,000 per life saved with a range of $317,000 to $49,423,000 across all respondents.	o The scenarios were reasonably plausible and well defined, but presentation was too terse and probably confusing. o Should be interpreted as a pretest only.
Murphy (1979)	Estimates were not defined for any specific risk. Focus of the study was on the risks of immediate treatment for illness versus waiting until diagnostic test results are available.	Used an indirect valuation approach defining a value of life in terms of the pleasure derived from life's activities.	Respondents were asked to rate the relative pleasure of life activities such as sleeping, eating, working and leisure, and to estimate the compensation necessary to induce them to give up a few hours leisure by working overtime.	o A non random sample of 40 patients and staff at a hospital in Lansing, Michigan was asked to estimate time spent at and relative pleasure of various activities. o For those who were employed, willingness to accept compensation to give up some leisure was used to obtain an implied estimate of the value of the net loss in pleasure from working overtime.	Implied value per life was an average of $2,937,000. The author extrapolated this estimate from the value of pleasure from life's various activities that was estimated from the survey results.	Tradeoff used to obtain an implied value of life was based on the value of a marginal change in activities. Applying this value to all pleasure is probably not a valid extrapolation.

Table 4-1

Contingent Market Studies Summary Table

(continued)

Study	Risk	Unique Aspects	Hypothetical Scenario	Survey Procedures	Results 1982 Dollars	Comments
Frankel (1979)	Risks of airline accident fatalities and changes in life expectancies from unspecified cause.	o Hypothetical changes in risks of longevity were carefully communicated. o Some interesting comparisons were made between changes in life expectancy and guaranteed changes in life span.	Realistic markets were not formulated for most questions. Respondents were, for example, asked their willingness to pay for a magic amulet that would ensure uninjured survival of an airline flight.	o A non random sample of 169 faculty members and a few executives at the University of Illinois responded to the questionnaire. o Two levels of risk reduction were presented for airline fatalities -- a reduction of current risks to zero and a reduction of a hypothetically much higher risk to zero.	o Implied value per life was an average of $3,922,000 for the reduction in risk from current levels and was $60,000 for the much larger reduction in risk. o Life expectancy questions revealed significant risk aversion and on one case a life value of $1.78 million.	o The lower value per life was based on an unrealistically high risk of airline accident fatalities. o Unrealistic and vague hypothetical markets weakened the questionnaire.
Mulligan (1977)	Risks of fatal and nonfatal injury from nuclear power plant accidents.	Examined both willingness to pay to obtain reduced risks and willingness to accept compensation in exchange for higher risks.	Hypothetical increase in monthly utility bills in order to fund increased safety measures or decreases in bills in exchange for increased risks.	o A random sample of households in Lewiston, Pennsylvania, provided 82 responses. o Several different risk increments were presented numerically with an introduction describing the kinds of injuries that can result from a nuclear plant accident.	Average value per life saved implied by the WTP responses ranged from $71,000 to $322,320,000 assuming the questions referred to annual risks.	o Questions were poorly designed in that the time period was not defined making the risk level ambiguous. o Some risk levels considered were unrealistically high compared to estimates of actual risks of nuclear plant accidents.

able for public policy analysis. They have not paid much attention to the emerging literature on contingent market approaches for obtaining estimates of values for nonmarket goods. Two of the studies conducted some pretests of their survey instrument, but all of them could have benefited from the refinements in survey design that have been evolving in other areas of environmental quality valuations.

The value of life estimates implied by the responses to these surveys vary widely both within studies and across different studies. These results are summarized in Table 4-2. The studies do indicate that most respondents were willing to put positive dollar valuations on decreases in risks and that they were willing to make the effort to answer these questions seriously and reasonably.

All of these studies had some problems in the presentation of the scenarios, the hypothetical market and the change in risk being valued. Acton's questionnaire was probably the best such presentation. The suggested actions for reducing risks of heart attack fatalities were well defined and realistic; however, the payment vehicle by which these programs would be supported was left rather vague and although all the necessary information about the change in risk to be valued was given, it was rather confusing. The Jones-Lee questions were fairly well presented in terms of the levels of risk to be evaluated and the market mechanism, but the scenarios in which these choices might have to be made were not well developed and the presentation presumed a well educated audience. The Frankel and Mulligan surveys were both rather weak in the realism and detail of the scenarios. The Mulligan survey was especially flawed in terms of the description of the risks to be valued. Future survey efforts need to take pains to develop realistic and detailed scenarios and to present the tradeoff the individual is being asked to consider in a straightforward and simple manner. A realistic context in which the individual might have to make such a tradeoff should be carefully described.

Only in the Mulligan study were respondents questioned about their unwillingness to answer valuation questions. Mulligan found that over 80 percent of the respondents said they were unwilling to accept any compensation to allow risks of nuclear plant accident injuries to rise. Many of the explanations offered for this refusal reflected an aversion to the idea of being compensated for allowing increased risks that would also affect other people. This difficulty suggests that questions about tradeoffs concerning risks to the public should be phrased in terms of willingness to pay for reductions in risks as this is likely to be a more acceptable concept. This also indicates that respondents were having trouble thinking about the risks to themselves alone as they were directed to do by the introduction to the questionnaire. If respondents are not distinguishing how much they themselves are affected by the risks from how much friends, family and fellow human beings are also affected, this could be influencing willingness-to-pay estimates as well. This might be mitigated by careful presentation of the question, and by describing a payment mechanism whereby everyone pays equally.

Other kinds of problem bids also need to be explored. Frankel found a rather high percentage of zero bids and very high bids relative to the means. These could be true valuations indicating a great deal of variation across people's preferences or they may indicate some difficulty with the question. Probing people's reasons for such bids would be helpful in deciding how to handle them in the analysis. Zero bids that were given because the respondent felt he should not have to pay for safety, for example, should probably not be used in the calculation of the sample means. Acton and Jones-Lee also found some inconsistent or illogical bids over different increments of risk. These might indicate confusion about the questions that could be cleared up during the interview process.

It is not expected that willingness to pay per life saved will be constant across people or across differences in the level and type of risk. The results of these studies provide some indication of the nature of these nonlinearities, but several questions remain. The Mulligan study found that higher incomes were associated with higher willingness to pay for reduced

TABLE 4.2
Summary of Value of Life Estimates from Contingent Market Studies[1]

Study (Year Dollars)	Initial Level of Risk	Increment of Risk	Average Value Per Life (Thousands/1982$)	Nature of Risk Examined
Acton (1972)	4×10^{-3}	2×10^{-3}	$64	heart attack fatalities
	4×10^{-3}	10^{-3}	$98	
	2×10^{-2}	10^{-2}	$17	
	2×10^{-2}	5×10^{-3}	$27	
Jones-Lee (1975)	0 to 4×10^{-5}	2×10^{-6} to 2×10^{-5}	$317 to $49,423 (mean = $5,343)	airline accident fatalities
Murphy[2] (1978)	--	--	$2,937	--
Frankel (1979)	1.5×10^{-6}	1.5×10^{-6}	$3,922	airline accident fatalities
	10^{-4}	10^{-4}	$60	
Mulligan[3] (1977)	10^{-4}	9×10^{-4}	$71	nuclear plant accident injuries
	10^{-5}	9×10^{-5}	$498	
	10^{-6}	9×10^{-6}	$4,151	
	10^{-7}	9×10^{-7}	$34,760	
	10^{-8}	9×10^{-8}	$322,320	

1 This table is for summary and comparison purposes. Before using the estimates, the reader should understand the assumptions and procedures by which they were obtained.

2 This estimate was not linked to a specific risk or risk increment although the author states that it is relevant only for small changes in risks.

3 These are based on the assumption that the survey question referred to annual risks and that all injuries are fatal.

risks. The Acton study, however, found that income and wealth were not significant influences on the bids offered.

If safety is similar to a typical market good, then additional units will provide smaller and smaller increases in utility. This means that for a given starting point, it can be expected that value per life saved will fall as the number of lives saved increases. This was confirmed in the Acton study where respondents were asked their willingness to pay for a reduction from .004 to .002 and then from .004 to .003. The second mean bid was more than half of the first indicating that the first .001 reduction was valued more than the second .001 reduction.

Another expectation regarding nonlinearities in risk valuations is that at higher risk levels, people will be willing to pay more for an incremental risk reduction than they would be willing to pay if they were at a lower level of risk. People at higher risk levels have less probability of being able to enjoy future income and wealth and are therefore expected to be willing to part with more money for the decrease in risk than would a person at a lower risk level, even though the change in risk is the same for both individuals. The contingent market studies have not provided any useful evidence on this question because in each case where higher risk levels were hypothesized, the increment of risk being evaluated was also changed. Problems may have also resulted because the higher initial risk levels suggested in these surveys were often outside the range that most of the respondents would consider realistic for the topic being discussed. This question could be more carefully considered in future survey efforts by keeping increments constant and changing the initial risk levels, and by using realistic ranges of risks.

The work of Tversky and Kahneman (1981) may shed some light on some of the apparent inconsistencies observed in the survey responses and on the importance of how the questions are phrased. They have developed the proposition that expected utility theory (individuals make choices that maximize expected utility) does not adequately predict peoples' preferences with respect to risk taking and that their alternative "prospect theory" is a better predictor of peoples' choices in the face of risks. They have found several systematic patterns: (1) people value risk taking differently if it is presented as a potential loss or a potential gain, (2) breaking down the probabilities into steps can result in different valuations even though the net result is the same, and (3) marginal losses or gains are less important as they become a smaller fraction of the total loss or gain being considered.

The first point is consistent with the Jones-Lee results that compensation required to accept a higher risk was more than the willingness to pay to obtain a comparable decrease in risk. The third point is consistent with the Acton results showing a decreasing marginal value of additional lives saved when starting from the same initial risk level. There is no such clear illustration of the second point, but it should be noted that Acton's results, which imply low values per life compared to most of the other results, are based on questions that present the risks of heart attack deaths as a two step probability. It is not clear whether Tversky and Kahneman's results refute the validity of expected utility theory or simply demonstrate systematic difficulties people have in interpreting probabilities, but they clearly demonstrate that how the question is phrased and presented can have a significant influence on the responses obtained.

The Murphy study was included because it is an example of an indirect valuation approach using a survey effort. Respondents were asked to make judgements about the value of how they spend their time during a typical week in pleasure, not dollar terms. The tradeoff between pleasure and income was derived from a second question so that an implied value of life could be estimated. Although there were problems with several assumptions made along the way in this study, the idea of indirect valuations is appealing when things are being considered that people do not usually think of as being purchased or traded. It may be easier for people to think in terms of, for example, time they are willing to spend to save lives than money. The problem with any approach of this nature is that the eventual conversion

to dollars that must be made for benefit-cost analysis is seldom straightforward.

4.3 Applications Issues in the Contingent Market Approaches

Economists have long been skeptical of survey approaches because they are suspicious that what people say they want or are willing to pay for, and what they will actually part with money in order to obtain, are two different things. The challenge of contingent market approaches is to design a survey instrument that will effectively elicit the desired information. Valuations received with contingent market approaches have often varied substantially with small changes in the application of the technique and must, therefore be carefully designed and monitored. One of the most important problems encountered in these approaches is the design of questions so as to minimize perception errors and biased responses. Survey research has found that responses are most accurate when the questions are about topics or decisions that are familiar to the respondent, when the questions are realistic and credible, and when the time and inconvenience of answering the questionnaire is low. (See Crespi 1971, Erskin 1972, and Ajzen and Fishbein 1977.) This means that a question about willingness to pay for safety needs to be presented in a context in which the respondent can imagine having to make such a choice. For example, a question about how much the respondent would be willing to pay in higher automobile prices for improved or increased safety equipment in an automobile is probably much more effective than a question that simply asks how much the respondent would pay to increase his life expectancy by a specific number of years. In the first case, the payment mechanism is concrete and realistic and the choice is one that the respondent could imagine having to make, whereas the second one is vague and difficult to identify with.

The applicability of the contingent market approach to the valuation of risk depends on the ability of respondents to weigh the importance of small changes in risks. In most ordinary circumstances, the risks faced by individuals in any particular activity are very small. The average annual risk of fatality in an automobile accident is, for example, about .0003 (3 in 10,000), while for fatal accidents on the job for blue collar workers, it is about .0002 (2 in 10,000). People do make decisions in their lives that involve risks of these magnitudes and will expend time and money to reduce such risks by a small amount, but the survey questions must adequately communicate the nature and size of the change in risk being considered in terms of familar experience. Contingent market approaches, as well as the market approaches, could profit from a better understanding of people's attitudes and judgement processes about what risks are acceptable for what benefits. Although contingent market studies do not rely on interpreting observed behavior, understanding typical behavior and judgement processes with respect to risk would help the researcher pose more meaningful questions.

Usefulness for Policy Analysis

Careful application of these approaches can provide useful input for environmental policy decisions. The studies performed to date have not used state-of-the-art techniques as found in the current contingent valuation literature and many improvements are possible.

Contingent market approaches have the advantage of a great deal of flexibility. Constrained only by the necessary realism of the hypothetical scenarios, the approach can be structured to address the specific question at hand. It can therefore be used in circumstances when no appropriate market information is available. The approach is also easily and quickly implemented, but a careful survey effort can be expensive, especially if personal interviews are conducted.

Contingent market approaches can also be used in conjunction with questions about attitudes and opinions on environmental policy. Such information could help to verify the interpretation of contingent market responses and the results of actual market approaches. It may be that market distortions and lack of information prevent observed behavior from reflecting

true preferences. Surveys might therefore provide better willingness-to-pay estimates. It may also be possible to have respondents describe tradeoffs they would be willing to make in other than dollar terms. They could, for example, be asked how much time they would spend to reduce the risk of a certain kind of accident. Although this approach would avoid the problem of requiring respondents to put dollar values on something they do not typically think of as a marketable item, the problem still remains of having to put dollar values on time or whatever measure is used if the results are to be used in benefit-cost analysis.

CHAPTER 5.0
OTHER VALUE OF LIFE AND SAFETY ESTIMATION ISSUES

Chapters 2 through 4 have summarized the available empirical estimates of the willingness to pay for changes in risk levels. This section will summarize some considerations that are relevant to estimating the willingness to pay for changes in risks, but that have remained largely outside the scope of the currently available empirical studies.*

5.1 Properties of an Individual's Willingness to Pay for Changes in Mortality Risks

The hedonic wage-risk studies reviewed in Chapter 2 do not provide information on the properties of an individual's willingness to pay function for changes in risk. Instead, they map out a set of market clearing wage-risk combinations. Contingent valuation studies can be used to derive estimates of an individual's demand curve for safety, but the poor quality of existing studies limits their usefulness. A number of researchers (Weinstein, et al., 1980; and Thaler and Gould, 1982) have used decision theoretic approaches to explore the likely properties of individual willingness to pay curves. The principal conclusion to be drawn from these studies is that there is no unique value per life saved. This conclusion rests on two findings:

1. The willingness to pay for a reduction in the risk of mortality depends on the amount of the reduction and the initial probability of death.

2. The willingness to pay also depends on whether the decision is ex ante (e.g., medical insurance or preventive medicine) or ex post (e.g., after-the-fact intensive medical care).

The implication of this first finding is that the cost effectiveness of programs to reduce mortality risks cannot be evaluated solely by dividing the cost of the program by the number of lives saved. Instead, the value of the reductions in risks will depend upon the specific individuals whose risks have been reduced and their base risk level. This implies that it may be desirable to devote more effort to reducing risks for those with high base risk levels.

The second finding states that the value of a reduction in risk depends upon whether the reduction is evaluated ex ante to a particular health event that increases an individual's risk or ex post to the event. As a result, the appropriateness of ex ante versus ex post valuations is important in the design of empirical studies. An example can be given in the context of kidney dialysis. Each year approximately one out of 30,000 people suffers kidney failure and becomes a candidate for dialysis. Without dialysis, the individual will certainly die, with dialysis the individual is likely to live. The theorem states that if each one of these 30,000 individuals were asked what compensation he or she would be willing to accept ex ante to having kidney failure to forego the availability of a dialysis machine, the sum of these estimates over the 30,000 people, would be less than the compensation required by the one individual to forego having access to the dialysis machine after having had kidney failure. This difference in the selling price per expected life saved between ex ante and ex post evaluations holds whenever the individual is risk averse or risk neutral with respect to assets.

The fact that ex post willingness to pay tends to exceed the ex ante willingness to pay seems to support our societal tendency to invest much more heavily in

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* A more detailed treatment of each of these topics can be found in the main report.

health care for the sick patient than in preventive health measures. As the collective public pays a greater share of health costs, it becomes more compelling to view the appropriateness of these expenditures from an ex ante perspective.

5.2 The Choice Between Ex Ante or Ex Post Risk Valuations in Policy Assessment

Since ex ante and ex post willingness to pay estimates will often differ, there is a question as to which value is the most appropriate for policy assessment. Broome (1978) argues that, of these two, the ex post valuation is the correct one. An ex post valuation is made at the time the project is implemented and when all the details of its effects are known, including who will be hurt. Since ex post decisions are based on more information, Broome contends that they should be preferred. Most researchers, however, have argued in favor of using ex ante valuations (see Thaler, 1982; Thaler and Gould, 1982; and Mishan, 1982). Thaler (1982) makes the following arguments in favor of ex ante valuations:

1. Few projects are instantaneous. Decisions on whether to implement a risk reducing project may have to be made before the affected individuals are identified.

2. The choices made in ex ante valuation studies are egalitarian. All individuals know the forthcoming outcomes and probabilities.

3. The ex ante "willingness to pay of individuals with low survival probabilities should be discounted, because their willingness to pay is based in part on their low survival opportunities. Since they are likely to die, the dollars they are offering are in some sense worth less to them." It is only their inability to trade risks with individuals in the low risk groups that allow them to outbid those groups.

4. In the final state, ex ante choices will save more lives and conserve more wealth. To the extent that these are the variables in the decision models, it is hard to fault ex ante choices.

Although there is not a clear consensus in the literature, the arguments for the use of ex ante, unidentified risk valuations in policy evaluation are persuasive. This has particularly important implications for any future contingent valuation studies since the hypothetical markets can be designed to value either ex ante or ex post risks. Given the arguments, the ex ante valuation seems superior for policy assessment.

5.3 The Valuation of Different Risk Types

Policy scientists have observed that individuals appear to place different values on different types of risk. For example, individuals seem to be more averse to accepting risks that are felt to be involuntary, i.e., risks imposed on individuals by society. The classification of risks as voluntary or involuntary is only one factor that has been used to characterize different types of risk. For example, Litai (1980) presents twenty-six different risk characteristics that have been used to classify risk types.* The basic policy issue raised by this literature is whether people's willingness to pay for reductions in risk varies across risk types. A related question is whether societal decisions should reflect these different valuations, if individuals do appear to value different risk types differently.

Much of the recent literature has been concerned with risk conversion factors (RCF's). The basic premise of the approach is that actual behavior is useful for revealing existing social preferences and values for different risk types. The underlying assumption is that, over time and through a trial and error process, a rough equilibrium state between risks and commensurate benefits has been arrived at by

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* The literature addressing risk characteristics includes C. Starr (1969); W. D. Rowe (1977); H. J. Otway (1977); and Fischhoff et al. (1978).

society. By observing society's behavior towards risk, a quantitative relationship (i.e., risk conversion factors) can be established between different types of risks, and between risks and benefits.

5.3.1 Risk-Benefit Ratios as Conversion Factors

One of the clearest examples of this societal revealed preference approach is C. Starr (1969). Starr concluded that the public is willing to accept voluntary risks that are roughly 1000 times greater than involuntary risks, holding benefits from the two risk taking activities constant. The Starr analysis admittedly used crude data and the results should be viewed as suggestive rather than an attempt to provide actual numbers for policy purposes.

The method used by Starr was to develop quantitative correlations between the risk-benefit ratios associated with different activities. The risk measure used was the statistical probability of fatalities per hour exposure to the activity. The estimates of social benefits for the different activities were expressed in terms of annual dollars. In the case of "voluntary" activities, the amount of money spent on the activity was used as an estimate of the benefits (e.g., hunting and smoking). For transportation benefits, the monetary cost and time saved by the particular mode relative to a slower competitive mode (e.g., airplanes compared to automobiles) was taken as a measure of the benefits. In the case of involuntary activities (e.g., electric power), an estimate of the contribution of the activity to the individual's annual income was used. The final piece of data used in Starr's analysis was a correlation between mining accidents and injuries. The severity rate of injuries was found to be roughly approximated by a third power function of wages (i.e., the miners risk level was proportional to wages raised to the third power: risk $\sim$wages^3). With these data, Starr compiled the risk comparison relationship shown in Figure 5.1.

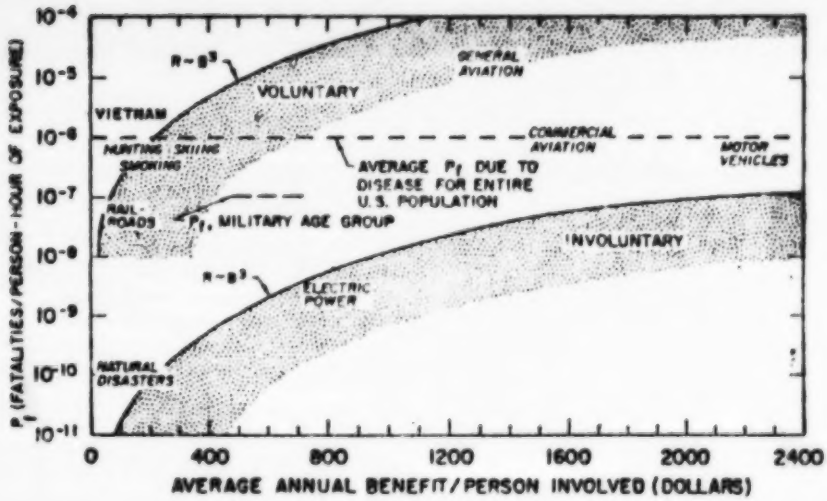
Choosing a risk level of 1×10^{-7}, Figure 5.1 shows that the annual benefits must be approximately \$100 per year before an individual is willing to accept that level of voluntary risks. If the 10^{-7} risks are viewed as involuntary, then the individual requires compensation on the order of \$2000 per year. This comparison indicates that society is far more willing to accept voluntary risks than involuntary risks.

The proper interpretation of Starr's risk-benefit comparisons is problematic. The data used in the comparison are extremely rough and in some cases questionable. For example, using both the money spent on air travel as well as the value of time saved over automobiles may be double counting the benefits. The willingness of individuals to pay the higher costs of airplane travel is at least partially due to the value of the time they save. Also, the use of expenditures for measuring the benefits of hunting and smoking is at best only the lower bound since it ignores any consumer surplus. For example, individuals may be willing to pay costs in excess of their current levels to engage in hunting and smoking. Taking this into account could greatly increase the benefit-risk ratio of these activities. This would tend to reduce the apparent disparity between benefits required to undertake voluntary risks and benefits required to undertake involuntary risks observed by Starr.

The Starr comparison is based on only eight data points: four voluntary activities (general aviation, railroad travel, skiing, and hunting), and four involuntary activities (natural hazards, electric power, commercial aviation, and motor vehicles). Two additional risks were included as benchmarks. The risks associated with the Vietnam war (which were classified as voluntary risks with benefits of \$30 x 10^9 based on the annual expenditure) and the risks from all disease were used as reference points. Starr's comparison has been criticized by several researchers (Otway and Cohen, 1975; and Fischhoff et al., 1979). These studies showed that regression lines could be fit to the Starr data in several different ways yielding diverse results. Otway and Cohen (1975) fit regression lines for the data and found that there does appear to be a greater tendency to accept voluntary risks as opposed to involuntary risks; however, the difference between acceptance of these two kinds of risks was considerably

FIGURE 5.1

Risk (R) Plotted Relative to Benefit (B) for Various Kinds of Voluntary and Involuntary Exposure



Source: Starr (1969)

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smaller than found by Starr and diminished to zero as benefits increased.

Extensive analysis of the few data points compiled by Starr is probably not warranted. They should be viewed as generating plausible hypotheses that deserve testing in a more detailed study. Fischhoff et al. (1979) extend Starr's conceptual approach to the comparison of the risks and benefits of 25 activities and technologies. Their results also show individuals appear to be more willing to accept voluntary risks; however, the data points are quite dispersed so that the relationship is not very strong.

5.3.2 Risk Conversion Factors

Rowe (1977) and Litai (1980) develop risk conversion factors to compare different types of risks. Their approaches must be carefully distinguished from those used by Starr (1969), Otway and Cohen (1975), and Fischhoff et al. (1979) since the benefits of incurring the risks play no part in the analysis. The focus is only on comparisons across the different levels of risk individuals are willing to accept, without regard to benefits. The Litai study will be the focus of this discussion. The differences between the Litai and Rowe approaches is that Litai works with actual distributions of risks while Rowe uses only average risk levels. Otherwise, the two approaches are essentially identical.

The premise of the Litai study is similar to Starr's revealed social preference approach. They both assume that society has arrived at a rough balancing of various risks by trial and error. Litai also observes that for each risk type, the actual risk level for separate individuals is spread over a wide range, often extending over several orders of magnitude. In addition, the process by which society and individuals determine the level of acceptable risk involves a number of human factors encompassing philosophical and psychological factors, as well as potential damage to property and materials. The risks classified by Litai were those where fatalities were considered to be the predominant concern.

The method used by Litai is based on actuarial risk data and therefore the data are derived from the actual behavior of people. Litai felt that differing types of risk could be summarized by the nine characteristics presented in Table 5-1. A dichotomous scale was used in assigning the risk characteristics. For example, with respect to the characteristic volition, the risk is classified as either voluntary or involuntary. Litai argued that this dichotomous classification is an underestimate of human sensitivity, but is a valid approximation with abundant examples of its use in the literature. The assumption is that individuals do not perceive small changes in the parameters and, therefore, a dichotomous representation is a satisfactory approximation.

The first step in Litai's analysis was to classify all the risks by the nine characteristics. In most cases he felt there was a clear choice regarding the characteristics the majority of individuals would assign to each risk. For example, automobile travel was assigned the following nine characteristics: voluntary, ordinary, manmade, immediate, continuous, controllable, old, clear, and necessary. While it is not clear that every person would pick these exact characteristics, it was felt that they represent the opinions of the vast majority. In cases where the assignment of characteristics were not clear (e.g., homicides), the risks were not used. Some risks could be classified in both categories. For example, nuclear energy could have both immediate and delayed fatalities. Both classifications were then assigned to that risk.

The next step was to search for risks that only differed with respect to one characteristic. The risk conversion factors were estimated by dividing one risk distribution by another risk distribution that varied in only one of the characteristics. Table 5-2 shows the risk conversion factors that were calculated for each characteristic. These risk conversion factors can be used to calculate mean values of each risk type accepted by U.S. society. These are shown in Table 5-3. Litai points out that these values cannot be viewed as currently acceptable risks when subgroups in the populations are affected differently. These risk levels are average values of a distribution and many groups may accept substantially lower or higher risk levels. Another use of these risk conversion factors is to make different types of risk comparable. According to Litai, the risk conversion factors can be used to show why society spends "unreasonable" sums to avert selected deaths and refuses to spend less money in other circumstances.

The usefulness of these risk conversion factors in policy analysis is questionable. As calculated by Rowe (1977) and Litai (1980), they do not consider the benefits of incurring the risks. If the benefits of one of the risks (say, Risk 1) are 100 times higher than the benefits of a second risk category (Risk 2) used to construct the ratio, then it would not be surprising that individuals would be more willing to accept higher levels of Risk 1. The implicit assumption incorporated in the use of these risk conversion factors is that the marginal benefits associated with an additional increment of each risk type are equal across all risks. This is not likely to be the case since risk is only one attribute of a product or activity comprised of a number of attributes of varying levels. Marginal utility may be equated across all products or activities purchased by an individual, but, since risk will tend to be fixed or at least not infinitely variable within activities, there is no reason to assume that marginal benefits of incremental risks will be equated across activities. Thus, the different magnitudes of benefits associated with different types of risks could well account for substantial portions of the risk conversion factors found by Litai. This is particularly true since many of these risk conversion factors are based on the quotient of only two risk types. Still, if it were possible to gather data on benefits associated with the different risk types, better estimates of risk conversion factors could possibly be obtained.

5.3.3 Conclusions Regarding the Valuation of Different Risk Types

The evidence accumulated by the studies that have researched this topic indicates that society may place different values on different types of risks. The available

TABLE 5-1

Risk Characteristics Used by Litai (1980)

Characteristic	Classification	
Volition	Voluntary	Involuntary
Severity	Ordinary	Catastrophic
Origin	Natural	Man-made
Effect manifestation	Immediate	Delayed
Exposure Pattern	Continuous	Occasional
Controllability	Controllable	Uncontrollable
Familiarity	Old	New
Benefit	Clear	Unclear
Necessity	Necessary	Luxury

empirical data are suggestive of these differential valuations and possibly indicate the likely sign of risk conversion factors, but the usefulness of these estimates in policy analysis is questionable.

The risk conversion factors and comparative risk-benefit ratios indicate that society does appear to act as if different risks have different values. However, why these risks are valued differently is still an interesting question. One possible reason could be the existence of certain psychic costs with different types of risks and differences in how the risks are perceived. Another reason could be that benefits have been poorly measured in these comparisons. Going back to Starr's and Fischhoff's analysis, the use of gross expenditures on cigarettes and motorcycles may dramatically underestimate the benefits associated with these "voluntary" activities. If properly accounted for, these risk-benefit ratios might be considerably lower and, therefore, closer to the risk-benefit ratios of activities or products associated with "involuntary" risks. Related to the proper accounting of benefits in these studies, it may be the case that individuals value the flexibility associated with the acceptance of voluntary risks. Voluntary risks are usually associated with activities that could be discontinued in the future if the individual's risk preference structure were to change. This is not the case with many involuntary risks (e.g., the widespread use of nuclear power). The flexibility associated with voluntary activities allows individuals to appropriately balance their risk portfolios under a wide range of future circumstances. This implies that there may be some form of option value associated with voluntary risks that is not present with involuntary risks. All of these factors could contribute in varying proportions to the observed risk taking behavior examined in these studies.

A final point to be made is that all of these studies assume that society, through a trial and error process, has arrived at some sort of satisfactory equilibrium with respect to balancing different types of risks and benefits. If the individuals who collectively decide on society's risk taking base these decisions on biased information regarding the risks associated with different activities (e.g., from the news media), an undesirable equilibrium may result. Further, if individuals are poor probability processors, this situation could be aggravated. Thaler (1982) points out that "most individuals are rather poor at budgeting their money but would not want the government to emulate their ineptness. "They may prefer having an expert make their life-saving decisions for them just as they would hire an accountant to do their budgeting if they could do so cheaply.

TABLE 5-2

Risk Conversion Factors (Litai, 1980)

Risk Characteristics	RCF Estimated*	Probable Error Factor
Delayed/Immediate	30	10
Necessary/Luxury	1	10
Ordinary/Catastrophic	30	10
Natural/Man-made	20	10
Voluntary/Involuntary	100	10
Controllable/Uncontrollable	5	10
Occasional/Continuous	1	10
Old/New	10	10

* These mean, for example, that immediate risks require 30 times more compensation than delayed risks.

5.4 Measuring and Defining Risks to Life and Safety

This section discusses several dimensions of risks to life and safety that are important for policy assessment but have been only minimally addressed in empirical studies. Three issues are examined in this section. The first is whether expected years of additional life should be adjusted for the expected quality of life. The second issue concerns a suggested procedure for incorporating externalities associated with risks (i.e., indirect effects on others of society) and collective risk aversion with respect to catastrophic accidents. The third issue is the consideration of risks of nonfatal injuries and/or health problems.

5.4.1 Quality of Life Adjustments

Several articles have discussed the appropriate measures for the analysis of policies designed to reduce mortality risks. The two most often used measures are number of lives saved and years of life preserved. The selection of the measure of mortality benefits can affect the policy decision where one policy is preferred if the benefit unit is total lives saved while another policy is preferred if the unit is total additional years of life. In most actual policy assessment applications, the unit used has been the number of statistical lives lost or saved. The use of total lives saved is due primarily to the existence of empirical estimates for the value of a statistical life from the wage-risk and consumer behavior studies discussed in Chapters 2-4. Zeckhauser and Shepard (1976) have suggested another approach which uses years of additional life adjusted for the quality of life during those years. This quality of life adjustment could be particularly important for comparing risks of fatalities that are preceded by a lengthly illness with the risk of instant death.

The unit of measure in the Zeckhauser and Shepard work is the quality-adjusted life year (referred to as a QALY). QALYs are tallied on a year by year basis and calibrated so that year with full function (i.e. no health impairments) would be assigned a QALY with the value of 1, and a year without life a QALY with the value of 0. Calibration of QALY values for years with partial impairment requires more information, but can be performed with procedures that have been used to calibrate multi-attribute utility functions. These

TABLE 5-3

Mean Values for Risk Types Accepted by U.S. Society (Litai, 1980)

			Controllable Risk				Uncontrollable Risk			
			Ordinary		Catastrophic		Ordinary		Catastrophic	
			Immediate Risk	Delayed Risk	Immediate Risk	Delayed Risk	Immediate Risk	Delayed Risk	Immediate Risk	Delayed Risk
Man-Made Hazard	Involuntary	Old Risk	1.3×10^{-6}	4×10^{-5}	5×10^{-8}	1.5×10^{-6}	3×10^{-7}	10^{-5}	10^{-8}	3×10^{-7}
		New Risk	1.3×10^{-7}	4×10^{-6}	5×10^{-9}	1.5×10^{-7}	3×10^{-8}	10^{-6}	10^{-9}	3×10^{-8}
	Voluntary	Old Risk	1.3×10^{-4}	4×10^{-3}	5×10^{-6}	1.5×10^{-4}	3×10^{-5}	10^{-3}	10^{-6}	3×10^{-5}
		New Risk	1.3×10^{-5}	4×10^{-4}	5×10^{-7}	1.5×10^{-5}	3×10^{-6}	10^{-4}	10^{-7}	3×10^{-6}
Natural Hazard	Involuntary	Old Risk	3×10^{-5}(?)	10^{-3}(?)	10^{-6}	-	6×10^{-6}(?)	2×10^{-4}(?)	2×10^{-7}(?)	-

scaling procedures are similar to the contingent market survey techniques discussed in Chapter 4.0. As an example of how these QALY values could be scaled, consider an individual who has a choice between living the rest of his life with a specific impairment or having an operation that could return full function, while leaving his expected life span unchanged. The operation has a probability X of being successful and a probability 1-X of being immediately fatal. The value of X that would leave the patient indifferent between having or not having the operation is the appropriate value for the QALY adjusted for that specific level of impairment.

The Zeckhauser and Shepard approach outlined above measures benefits of policies to reduce health hazards in terms of quantity and quality. Few applications of this technique have been attempted. In one application, Weinstein and Stason (1976) estimated the expenditures per QALY obtained from treatment for hypertension to be in the range of $3,000 to $20,000.*

5.4.2 Externalities and The Potential Usefulness of Decision Analytic Approaches.

Many of the empirical approaches have, most often due to limited data, been able to address only one dimension of the multi-dimensional risk valuation problem. That one dimension is the individual's willingness to pay for a reduction in the risk of death. However, there are externalities that could be important to the benefits calculation. These would include the value family members and others put on an individual's life and the indirect economic impacts that can affect society due to a large catastrophy with many fatalities, such as a dam break or airplane accident. Bodily (1980) and Keeney (1980) argue that risks which may result in a large number of fatalities cause greater political, economic and social turmoil.

For benefit-cost approaches to be more useful to policy makers, it is important that some of these additional levels of complexity be included in the analysis. Several recent contributions to the literature that have their roots in the fields of operations research and decision analysis offer some organizing principles that may be helpful in addressing some of these complexities (Bodily, 1980 and Keeney, 1980). The basic approach is similar to the QALY adjustment just discussed. The first step is to develop a utility function that contains the different dimensions of risk that need to be valued, such as the potential number of lives lost in a single incident (a catastrophy dimension), whether the risks are voluntary or involuntary, and externalities such as the effect on others. Once these dimensions are specified in a utility function with the standard properties, then the variables in the function are scaled and the constants specified in a manner similar to that used to scale QALYs. All of these approaches require subjective scaling of variables and valuation of the constants through an elicitation process where either decision makers or individuals are asked to judgementally estimate these parameters.

Bodily (1980) develops an approach to deal with several characteristics of risks and public attitudes that influence the value of safety programs. The characteristics included by Bodily are:

1. Individual risk preferences
2. Nonstandard background risks
3. The need to compare the value of life saving with that of injury prevention
4. Distinction between voluntary and involuntary risks
5. Possible psychological effects of risks
6. Bunching effects, where one incident involving n-individuals may be perceived as more serious than n incidents each involving one individual

* Other related studies that use different measures of health that could be useful in inferring a quality of life index are Franshel and Bush (1970) and Torrance (1976).

With respect to this last characteristic, Bodily observes that the social reaction to fatalities or injuries seems to be greater when a large number of people are affected in a single accident than when the same number of people are injured in several smaller incidents. Labeling this collective risk aversion, Bodily uses this to explain why safety standards in jumbo jets tend to be stricter than for smaller air craft.

The premise of decision analysis is that the explicit consideration of these trade-offs will allow better, more consistent decisions to be made. An interesting area of investigation might be an evaluation of combined economic/decision analytic approaches (i.e., utility functions scaled in dollars) in analyzing EPA programs affecting risks. This evaluation could be done in terms of the acceptability of the decision analytic process to policy makers and affected parties as well as whether better decisions will indeed be made.

5.4.3 Valuing Nonfatal Risks

This review has emphasized empirical estimates of the value of preventing fatalities, but many environmental issues concern the prevention of illnesses and discomforts that are not fatal. As a result, an important consideration will be the value of preventing or reducing risks of morbidity.

The bulk of the research that has been done concerning the value of preventing nonfatal health effects of manmade pollution has attempted to estimate the days lost from work, or otherwise restricted, attributable to effects of pollution. These lost or restricted days have then been valued according to the lost productive activity (typically measured as the individual's daily income) and in some cases the medical costs of the illness have been added as well.* Most applications have made extensive use of the work by Cooper and Rice (1976) which provides estimates of income lost and medical expenditures incurred due to a variety of illnesses. A basic problem with this approach is that it does not measure willingness to pay to prevent morbidity. It is not even clear that income and medical expenditure would be a lower bound on the individual's willingness to pay because in many cases the individual may receive sick pay and insurance payments to cover these losses. The individual's willingness to pay to prevent time spent sick is more likely to be a function of the pain and discomfort that accompanies the illness than of his wage, and there is little empirical evidence available on these valuations.

Cropper (1981) develops an innovative approach to the estimation of the benefits of reduced morbidity that goes a few steps beyond the previously used approaches. She develops a model of investment in health that incorporates the possibility that the individual can influence his health with a variety of preventive health care activities. The benefits of reduced pollution will therefore be the value of the reduction in time spent ill plus the value of the reduction in preventive health care activities that were being undertaken to offset the harmful effects of exposure to pollution. Cropper's estimates are double the estimates that would be derived from looking at only the time spent sick. This approach does not solve the problem of how to appropriately value the time spent sick (Cropper still uses the wage for this), but it provides a more realistic treatment of the individual's behavior with respect to the state of his health.

An important question for future efforts to obtain an estimate of the value of reduced morbidity is what constitutes an appropriate measure of morbidity. The most common measure has been work days lost due to illness, but this makes no distinction between a day spent in mild discomfort and a day spent in extreme discomfort. It also does not capture days spent sick but at work. A measure that has been used for nonworkers is "restricted activity days". These are the measures that have been used in some of the surveys

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* Examples using these approaches are Liu and Yu (1976) and Crocker et al. (1979). These and similar studies are briefly reviewed by Freeman (1979a).

that have provided data for estimation efforts. These surveys include the annual Health Interview Survey by the National Center for Health Statistics (used by Ostro, forthcoming) and the Michigan Panel Study of Income Dynamics (used by Cropper, 1981).

A whole range of possible approaches to estimation of willingness to pay to prevent morbidity needs to be explored. The Cropper study provides evidence that people make observable expenditures of money and time to prevent illness. These are the kinds of tradeoffs that need to be observed in a market approach to estimate the value of reducing morbidity, such as those reviewed in Chapter 3 concerning the value of reducing mortality. Those studies may in fact provide a starting point since the activities considered encompass both fatal and nonfatal risks. A few of the wage-risk studies also used measures of nonfatal injuries but the problems of overlooking worker's compensation make most of the resultant estimates questionable. Contingent market approaches might also be a fruitful avenue for obtaining estimates of willingness to pay to reduce morbidity. Questions about risks of morbidity might be less emotion-laden and easier for respondents to consider than questions about risks of death.

5.5 Perceptions of Risks

All of the willingness-to-pay approaches assume that people are able to judge for themselves what the benefits of various risks are. Several avenues of psychology research suggest, however, that individuals may have trouble making consistent rational choices with respect to risks. This may be the result of poor information or differences in the alternatives that the researcher may have overlooked. Whatever the cause, these problems raise the question of whether public policy should be based on preferences revealed by individuals' behavior. The studies discussed in this section do not provide conclusive evidence one way or the other, but they raise important questions that need to be addressed in future research.

5.5.1 Biased Perceptions of Risks

There is some evidence that individuals' perceptions of risks associated with various activities may be systematically biased. If errors in individuals' perceptions of risks are random, then the explanatory power of the statistical valuations reviewed in Chapters 2 and 3 would be reduced (i.e. the standard errors of the estimates would be increased), but the estimates would still be unbiased. However, if the errors vary in a systematic manner, then the estimates from these statistical studies will be biased. The contingent market approaches also rely on a consistent response by individuals to different levels and kinds of risks, although they could allow for some inconsistencies more easily than the actual market approaches.

Lichtenstein et al. (1978) conducted five experiments where individuals were asked to judge the frequency of lethal events. They found individuals' judgements of risk were consistent but systematically biased. Two kinds of bias were identified--one, there was a tendency to overestimate risks of relatively infrequent events (e.g., death from botulism) and to underestimate the probability of more frequent events (e.g., death from heart disease); and two, a tendency to overestimate certain risks characterized by wide media exposure, memorability or the imaginability of various events. To the extent that these systematic biases are present in individuals' perceptions of risk, the results of the studies reviewed in Chapters 2 through 4 may be biased.

Even though some of the possible causes of biases in individuals' risk perceptions were identified by Lichtenstein et al., the direction of the bias this may cause in the empirical estimates still is not clear. For example, a common view is that workers in risky occupations may underestimate the probabilty of lethal accidents due to being uninformed of the risks. In contrast to this, the Lichtenstein findings indicate that the likely bias in individuals' perception of the frequency of these low frequency occurrences would be to overestimate the risks. Bailey (1979) points out that in dangerous occupations, such as logging, accidental deaths and injuries are

everyday topics of conversation and for every severe or fatal accident, there are many near misses. Again following Lichtenstein et al., the effect of daily conversations concerning job risks and the increased vividness and imaginability of accidents from the many near misses would tend to result in workers' overestimating job risks. As a result, additional research on how individuals perceive the specific risks that are used in these empirical valuation studies is needed before the direction of potential risk perception biases can be identified.

5.5.2 Preference Reversal

The basic issue is whether there is a consistent theory of individual preferences that can be used to explain an individual's choices among uncertain or risky outcomes. The preference reversal phenomenon suggests, according to Grether and Plott (1979), that no optimization principles of any sort underly even simple choices.

The basic example used to illustrate preference reversal is an experiment where subjects are asked to pick one lottery from among two choices as the gamble they would prefer to take. After indicating a preference for which one of the lotteries in the pair they would rather play, the subjects are then asked to assign monetary equivalents to the two lotteries. This is done by putting the subject in the position of playing each lottery and asking them the amount of money they would take with certainty rather than play the lottery. For example, an individual facing a lottery with a fifty percent chance of losing $2.00 and a fifty percent chance of winning $20.00 might say that he would take a sure five dollars rather than undertake the uncertain lottery. The preference reversal occurs when the lottery that is preferred by the subject when selecting between the two lotteries is given a lower monetary value. It is easily shown that this is inconsistent with traditional forms of preference theory.

Whether or not this is an important issue for empirical studies placing a value on risks to life depends upon the pervasiveness of the preference reversal phenomenon. The studies examining the preference reversal phenomenon have used pairs of lotteries with essentially the same expected payoff. As a result, these experiments show whether individuals are capable of fine tuning their risk-reward portfolios. Since there is only a small difference in the payoffs for the two lotteries, the penalties associated with an incorrect decision are very small. If preference reversal were found for a pair of lotteries with larger differences in payoffs, then this would be of greater concern. When Pommerehne et al. (1982) increased the difference in the payoffs by up to 30 percent, the incidence of preference reversal declined.

In conclusion, the research on preference reversal has been quite limited and is deserving of more study. The evidence to date does not seem to contradict conventional preference theory. The only conclusion that seems warranted is that individuals may not be able to appropriately distinguish between risk-reward choices that have nearly the same expected payoff. If traditional preference theory is adequate for predicting choices among options that really matter, i.e., choices between options with distinctly different payoffs, then it is probably an adequate assumption in empirical risk valuation studies. Whether or not individuals can accurately select among nearly equivalent options at the margin is of far less importance.

5.5.3 Cognitive Dissonance

The theory of cognitive dissonance as advanced by Akerlof and Dickens (1982) is based on the concept that individuals not only have preferences with respect to states of the world, but also have preferences regarding the specific beliefs they hold, even if these beliefs contradict available information. In other words, individuals have flexibility in the beliefs they hold and can use this flexibility to choose beliefs that maximize utility.

Akerlof and Dickens refer to a great deal of anecdotal information that suggests that workers in dangerous jobs are often quite oblivious to the dangers involved. They go on to construct a theoretic model

of the labor market where people prefer to believe their work is safe. The worker chooses his beliefs according to whether the benefits exceed the costs. If the psychological benefits in terms of reduced worry and tension of believing one's job is safe exceeds the costs due to an increased chance of accident, the worker will believe the job to be safe.

Akerlof and Dickens cite the psychological evidence supporting cognitive dissonance. The strength of the evidence is in the great number of experimental results easily explained by the theory. Psychology experiments show that individuals with the same information will adopt beliefs that are in accord with their natural preferences. For example, people like to view themselves as having made good decisions. Investigations have found that individuals, after having made a decision (e.g. placed a bet on a horse or selected a home appliance), systematically hold stronger beliefs regarding the appropriate choice than individuals who are just about to make the choice, even when there has been no new information.

Akerlof and Dickens conclude that with additional research cognitive dissonance can be incorporated into economic models in a predictive manner. The importance of cognitive dissonance for estimating the willingness to pay for reductions in risk is clear. The tendency for workers or consumers to ignore risks because they are better off believing the risks are lower than actual levels will distort the risk valuations that are based on individuals' revealed preferences from market behavior. For example, Dardis (1980) used the purchase of smoke detectors as a measure of the willingness to pay for increased safety. The theory of cognitive dissonance would allow individuals to obtain utility from the belief that they were perfectly safe when in their home. If this belief were adopted, then purchases of smoke detectors would be lower than what would otherwise be the case and the observed value associated with the reduction in risk underestimated. Cognitive dissonance could potentially have important ramifications for risk assessment and could well explain some of the observed differences in the valuation of different risk types addressed in Section 5.3.

CHAPTER 6.0
CONCLUSIONS

In spite of the seemingly large amount of attention this topic has drawn, there has been no ambitious and consistent research program to quantify the willingness to pay for reductions in health risks. The empirical estimates that do exist should best be viewed as preliminary, that is, as pointing out additional hypotheses for analysis. The purpose of much of the research was not to provide empirical estimates for use in policy analysis but to test hypotheses regarding the workings of markets, particularly the labor market. This more limited goal made it less necessary to control for biases that would change the actual value of the estimated risk premium, but not change the direction of the effect. The most significant contributions to valuing reductions in risk have been made by studies focusing on the Department of Labor's occupational health and safety programs. Except for this area, the research has been scattered with work being done on different types of risks in different situations, and with little follow-up to test hypotheses identified in earlier studies. As a result, many of the important questions for environmental policy assessments have not been addressed in the empirical work.

This conclusion should not be viewed as reducing the importance of the contributions that have been made in this research area to date. Identifying hypotheses for research, defining problems that need to be addressed, and pointing out potential biases that can be controlled in future work are important and necessary steps in a developing area of research. However, this conclusion is not encouraging for policy makers who would like to use these estimates now. Still, careful analysis of the results may provide benchmark numbers for policy assessment. Since policy decisions are presently being made that trade off expenditures for reduced risks, it is important to make the best use possible of the currently available information.

The balance of this chapter will address the identification of reasonable ranges for values of a statistical life, the general conclusions from the wage-risk studies, the consumer market studies and the contingent market studies reviewed, and suggestions for research.

6.1 The Value of Life Estimates—Is There a Reasonable Range?

One of the goals of this review is to summarize the available empirical information on the value of life and safety which is applicable to environmental policy questions. The results of the wage-risk studies fall into two groups: those finding $400,000 to $600,000 (1982 dollars) per statistical life and those finding $1,000,000 to $7,000,000 per statistical life saved. All three of the consumer market studies found values per statistical life saved of about $300,000 to $500,000; these fall close to the lower range of the wage-risk studies. Two of the contingent market studies that considered risks of airline travel found values of $4,000,000 to $5,000,000 per life for changes in risks at levels close to the actual risk of airline travel. A few outlying results were found by contingent market studies--Acton found $20,000 to $100,000 per life and Mulligan found $70,000 to $300,000,000 per life. The outlying Acton results can possibly be explained by the type of risk analyzed. The risk being valued was a reduction in the risk of death after having had a heart attack by improving emergency services. Since the occurrence of a heart attack is a future event, possibly many years away, and even then not certain to occur, it is not surprising his estimates of willingness to pay for a reduction in these risks are lower than other studies where immediate death from accidents or fire were considered. The very low and very high results found by Mulligan are harder to explain, but problems with the design of the survey may be the cause.

Excluding these two studies results in two ranges of estimates--$300,000 to $600,000 and $1,000,000 to $7,000,000.

Given the wide variation in results and the variety of techniques used in risk valuation studies, it is difficult to select an appropriate value-of-life range for policy evaluation. One attempt to roughly define this range with respect to public health and safety policy was made by Bailey (1979). In a widely read and generally excellent review, Bailey (1979) tried to obtain an intuitive feel for where within, or between, these essentially two groups of value of life estimates a reasonable estimate might fall. He performed some calculations to develop benchmarks for the value of life that might be reasonable, then applied this test of reasonableness to the estimates. Bailey concluded that the lower range of value of life estimates, as typified by the Thaler and Rosen (1975) estimates, was reasonable while the higher estimates found by, for example, R. Smith (1974, 1976) and Viscusi (1978) were outside the range of reasonableness. Unfortunately, Bailey's test of reasonableness may not be entirely reasonable.

Bailey calculated a family's willingness to pay for a given reduction in the risk of death implied by the estimated values for a statistical life from the different studies. This willingness to pay was then compared to the average income for a family of four to see if it represented a "reasonable" fraction of their income, i.e., an expenditure that they could reasonably afford. Bailey used a reduction in risk from 6 deaths per thousand to 5.5 per thousand for his calculations. Using the lower range of estimates, Bailey estimated that a representative family of four with an income in 1978 of $18,500 would then pay approximately 3.8 percent of family income for this reduction in risk. Bailey concluded that this appears to be a reasonable expenditure.

Bailey then considered some of the higher estimates that came from the R. Smith (1974) and Viscusi (1978) studies. Taking the highest value from R. Smith (1974) as an upper bound and performing the same calculations gave an estimate of a willingness to pay of $10,000 for this reduction in risk for the family. This is about 55 percent of family income. Using this number, Bailey concluded that these higher value-of-life estimates are unquestionably too high.

There are several problems with Bailey's test of reasonableness. First and most important, the risk reduction being considered was far beyond the range of risks considered in the empirical studies. Second, the multiplication of the willingness to pay by the number of family members was inappropriate. The estimates from the wage-risk studies are for a wage earner in the family and the willingness to pay for a reduction in risks to a wage earner may be higher than an equivalent reduction for all family members due to the more severe impacts on the family from the loss of a wage earner.

The inappropriateness of the risk change used by Bailey deserves more discussion. He used a reduction in the annual risk of death for each household member of 5 per 10,000 (5×10^{-4}). The risk levels used by R. Smith (1974, 1976), Viscusi (1978a, 1978b) and Olson (1981) ranged from approximately $.15 \times 10^{-4}$ to 3.0×10^{-4}. Thus, the change in risk used by Bailey exceeded the entire risk to individuals working in the riskiest manufacturing industry used in their data sets. The mean risk level in these studies ranged from 1.0×10^{-4} to 1.5×10^{-4}. Reducing these risks by 50 percent would be a change of between $.5 \times 10^{-4}$ and $.75 \times 10^{-4}$, a reduction that is an order of magnitude lower than the change considered by Bailey. To provide an example of how large a 5×10^{-4} change in an individual's annual risk of death is, one need only compare it to the 2.7×10^{-4} average annual risk of death in a motor vehicle accident (car, truck or bus). Bailey used a change in risk that is close to twice as large as what would be needed to entirely eliminate the risk of death in a motor vehicle accident for all family members. This is far from the marginal changes in risk to which the results of the empirical studies are applicable.

A better test of reasonableness might consider what a family would be willing to pay to reduce by 50 percent the annual probability of the principal family wage earner being killed in a job-related acci-

dent. This would be approximately a change of between $.5 \times 10^{-4}$ and $.75 \times 10^{-4}$ in the risk of death. Using Bailey's adjusted values for Thaler and Rosen gives an average willingness-to-pay value of about $22.50 in 1978 dollars. Using the high value of life estimates from R. Smith (1976), we find this family would be willing to pay approximately $188.00 per year. Presented in this manner, both the lower group of value of life estimates and the higher group of estimates seem to fall in reasonable range.

Both economic theory and empirical evidence indicate that there is no reason to expect the value for a statistical life to be the same in all circumstances. It may vary depending upon the size of the change in risk being considered as well as with the initial risk level of the population being affected. Given this expectation, we will not try to say that the appropriate value for a statistical life for environmental policy purposes is a certain amount. Rather, the focus of this discussion will be whether such a value is likely to be greater than or less than the estimated values for a statistical life available to date.

In this effort, the wage-risk studies will be emphasized since as a group they are the most credible studies. These studies have consistently found a significant relationship between on-the-job risks and wages. This is a relationship that makes sense theoretically and is easy to believe exists. The consumer market studies have examined risk choices that are credible, but none of the results have been validated by repeated estimation in the same market. They are all subject to potential errors in the assumptions that were used to quantify the benefits of incurring the risks, or from reductions in risk. Also, these studies were unable to separate willingness to pay for reductions in the risks of death from risks of injury and property damage. For example, the Blomquist (1979) study is based on the assumption that the time it takes to buckle and unbuckle a seat belt is one basis for the individual's decision to use or not to use seat belts. The contingent market studies performed to date have not used state-of-the-art techniques and the results are potentially subject to a great deal of error. The most carefully performed contingent valuation study was Acton (1973), but he investigated the willingness to pay for post heart attack emergency services. This risk, conditional on having a heart attack, is difficult to relate to risk levels and health outcomes of other studies.

The wage-risk studies alone still give a range of $400,000 to $7,000,000 in 1982 dollars per statistical life. However, these estimates can be used to establish bounds on the value appropriate for environmental risks if the direction of the expected biases can be uncovered and are uniform in the same direction. If, for example, a lower bound can be established, then if the lower bound benefits of a program exceed the estimated costs, one would be reasonably confident that the program was in fact worthwhile.

The lower range of estimates from the wage-risk studies is from $400,000 to $600,000. This could be considered to be a lower bound to the value of a life for use in policy assessment if the directions of identified biases in the estimates are all downward. Unfortunately, the potential biases that have been identified are in both directions and may be large. Still, we are willing to argue that, subject to one critical uncertainty, these lower wage-risk estimates (i.e., $400,000 to $600,000) for the value of a life are likely to provide a lower bound to the value of preventing the life threatening risks that need to be considered in environmental policy assessment.

The key potential sources of biases that have been identified in these wage-risk studies are:

1. Whether the workers accurately perceive the risks of different occupations.

2. Whether the workers in the occupations examined are more or less risk averse than the general public.

3. Whether characteristics of occupational risks, such as voluntary versus involuntary or delayed versus immediate as discussed in Litai (1980) and

Starr (1969), make the wage-risk estimates different from what the estimates for environmental risks would be.

4. Whether the wage-risk premium captures only the risk of mortality rather than risks of both nonfatal and fatal injuries.

5. Whether potentially important explanatory variables have been omitted from the estimated equation and, therefore, bias the results significantly.

Of these five potential sources of biases, the first three are more likely, in our opinion, to result in a downward bias on the value of life estimates. The first source, workers' perceptions of risk, can in theory bias the estimated risk valuations up or down if worker perceptions show a systematic bias. There is, however, some evidence that workers are at least able to roughly rank jobs by their riskiness.* Still, there is likely to be considerable error in individuals' judgements of the actual amount of risk associated with different industries and occupations. This will have two effects on the results of wage-risk studies: one, the error-in-variables problem will reduce the significance of the coefficients on the risk variable; and two, the workers who tend to underestimate the risks of a particular occupation will gravitate to that job because they will be willing to accept a lower wage-risk premium.** This second effect will tend to produce a downward bias in the estimated value for a statistical life.

The second identified source of bias should clearly have a downward effect on the wage-risk premium. Most of the hedonic wage-risk studies that produced estimates in this low range used a data set comprised of the higher-risk occupations. It is generally hypothesized that less risk averse individuals will tend to take these jobs. This has been offered as one explanation for the different estimates of wage-risk premiums that have come from different data sets. If there is a bias, it would seem to be downward.

The third source of bias concerns different risk characteristics. Many environmental risks have different characteristics than those related to accidents on the job. In particular, there is some speculative evidence that the willingness to pay to avoid involuntary risks, i.e., risks over which the individual has little control, are greater than for voluntary risks. Although the characterization of risks as voluntary or involuntary is often not clear, it would seem that the decision to take a job would be more voluntary than most environmental risks.

The fourth and fifth identified sources of biases pose a problem because they will tend to result in an upward bias in the estimated value of a life. The fact that the risk premium may be capturing the compensation for risks of nonfatal as well as fatal accidents has a clear upward bias on the estimate; however, the extent of this bias is not clear. R. Smith (1974, 1976) was unable to find a statistically significant risk premium associated with nonfatal injuries indicating that workers' compensation may be adequate to compensate for the potential loss and no wage premium is required. Olson (1981) and Viscusi (1978b) were able to isolate the effects of nonfatal risks on the wage premium. In these cases, the estimated risk premium for fatal injuries was still in excess of $600,000. These results indicate that this potential upward bias, if it does exist, will probably not be large.

The fifth potential source of bias is the most significant problem. The willingness-to-pay estimates for changes in the risk of fatal accidents obtained from the hedonic wage-risk studies probably capture more than just the pure valuation of risk. High levels of risk are closely associated with a number of unpleasant working conditions, but in most cases the only measure of job unpleasantness used in the study was the risk of accident. Therefore, the hedonic wage-risk estimates probably reflect the wage premium required by that closely related package of unpleasant job characteristics, not just risk. This would produce an upward bias in the estimates.

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* Viscusi (1978a) presented data on whether the worker considered his job dangerous.
** This was discussed in Chapter 2.0.

Our conclusion is that, depending upon how one views the potential severity of the omitted variable problem in the hedonic wage-risk studies, the lower range of the value-of-life estimates from these studies probably reflects a lower bound to the value of fatal risks associated with environmental problems. Further analysis of the data sets and techniques used in these studies performed to date might yield further refinements to this estimate.

6.2 Suggestions for Future Research

This review has indicated that there has been no ambitious research program to quantify the willingness to pay for the reduction or prevention of environmental risks. Many important questions remain. One overriding issue is whether willingness to pay based on the revealed preferences of consumers or workers is an appropriate basis for valuing risks for use in policy assessment. Willingness to pay is the appropriate measure if it is based on accurate perceptions of risks by individuals and revealed by consistent behavior in actual markets or in response to hypothetical markets. However, the observations on human behavior that are used to generate willingness-to-pay estimates for reducing risks are subject to many potential emotional and informational biases. If individuals act irrationally with respect to certain risks, then should environmental policy follow the same irrational principles?

The discrepancy between the avoidance of voluntary and involuntary risks found by Starr (1969) and Litai (1980) is an example of where it may not be desirable to have policy follow revealed preferences. Although both studies suffer from severe data limitations and theoretic shortcomings, they have offered evidence that individuals value voluntary and involuntary risks differently. If a policy is adopted by the government that allocates more money for reducing "involuntary" risks than "voluntary" risks,* then more fatalities will occur than if this characteristic did not influence the allocation of revenues. Before such a policy would be adopted, it would be important to determine whether the government is simply adopting the irrational behavior of individuals or if there really are counterveiling benefits such as reduced psychological stress that make involuntary risks a bigger burden to society.

The conclusion that results from the above argument is that future research should try to better incorporate psychological findings within willingness-to-pay studies. Before willingness-to-pay estimates based on revealed preference are used in policy studies, a better understanding of the reasons for choices made by individuals to reduce or incur risks is needed. The work on probability judgements by Lichtenstein et al. (1978) and the work on cognitive dissonance by Akerlof and Dickens (1982) would be useful starting points for this type of analysis. A topic related to this is whether or not people value risks with different characteristics differently and, if they do, why? The most promising approach for obtaining some of this information seems to be a melding of the contingent valuation methods used by economists with the surveys used by psychologists in their research on risk perception and decision making. The contingent valuation studies performed to date have not, on the whole, been well implemented. Contingent market approaches provide a great deal of flexibility to pursue valuation questions specific to environmental policy decisions and to probe people's attitudes and preferences regarding the acceptability of certain risks.

Another area of research that could be fruitful is the use of utility functions as a means of organizing the valuation problem for a specific environmental risk. The basic approach is illustrated by Keeney (1980) and Bodily (1980). First a function is devised that incorporates all of the factors that are felt to influence the valuation of the risk. The function contains risk related variables that can be estimated such as the number of fatalities,

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* Again, recognize that it is hard to clearly differentiate between voluntary and involuntary risks.

the number of fatalities that occur at one event (to account for disasters, see Section 5.4.2), and the number and types of nonfatal effects. These variables are incorporated in a function where the constants (i.e., coefficients and exponents) are unspecified. The second step is to estimate values for these constants through a scaling process. These estimates could be obtained through use of surveys similar to those used in contingent market studies. As a result, decision theory approaches are actually very similar to the contingent market surveys used by economists. There is no reason why the constant terms in a decision theory framework could not be scaled in terms of dollars and incorporated in a conventional economic benefit-cost framework. A trial application of this technique could prove useful.

To summarize the other research recommendations, they will be presented by approach, i.e., hedonic wage-risk, consumer market and contingent market.

Wage-Risk Studies

The goal of many of the wage-risk studies was not to provide value of life estimates usable in environmental policy decisions, but was instead to test hypotheses regarding the operation of the labor market. Even though these studies are probably the most credible studies that have been done for valuing risks, it is not clear how useful these estimates are to the EPA. The types of risks that have been considered, namely accidents on the job, are not for the most part the kinds of risks that are of interest to the EPA. Transferability is difficult because we know so little about how differences in risks influence the valuation. Another problem with transferring results from wage-risk studies is that they consider only one population group. Some of the studies have considered a wide range of occupations and both men and women, but most considered only male blue-collar workers. In either case, those who are not in the labor force are not represented and how risk valuations may vary between labor force members and those who are not in the labor force, or those who are sensitive to specific environmental risks, is unknown.

Still, wage-risk studies may provide useful information. As was argued earlier, they might be useful in estimating a lower bound for many environmental risks. The principal problem with using the current wage-risk studies as a lower bound benchmark is the potential omitted variable bias resulting from the exclusion of job characteristics other than risk. Other unpleasant job characteristics, such as noise, dirt and uncomfortable temperatures, may be highly correlated with job risks.* A hedonic wage-risk study incorporating these additional variables could be useful in helping EPA determine a lower bound for the value of reducing or preventing environmental risks. Also, if risk conversion factors that could account for different risk characteristics and different populations could be determined from other studies, the results of the hedonic wage-risk studies could be transferred and used to value other risks.

Another problem area in wage-risk studies that could be corrected is that in most cases a functional form has been used that constrains the market equilibrium hedonic wage-risk function to be linear or convex. The theory indicates that a concave function is entirely possible and could be expected to occur if less risk averse workers are found in the riskier jobs. A more flexible functional form should be used in future wage-risk studies to allow the function to be either concave or convex.

Consumer Market Studies

The consumer market studies have a sound conceptual basis in that they have examined actual choices that people make with respect to risks. Data limitations have resulted in simplifying assumptions in the studies that examined risks of automobile accidents, which open the results

* Since the jobs with the highest risks are those associated with moving materials (i.e., assembly, loading and machining), it is likely that other unpleasant job conditions are correlated with job risks.

to a great deal of question. Also, the study that examined risks of residential fires was not able to use correct consumer surplus measures. The primary difficulty in consumer market approaches is that in cases where a risk is incurred in order to obtain a benefit (as in the case of automobile transportation) the benefit needs to be quantified to determine how much the consumer is having to be compensated in order to tolerate that risk. Questions also remain as to whether observed choices are based on adequate consumer information and on reasonably accurate perceptions of risks.

The usefulness of future consumer market studies for addressing EPA policy questions depends on whether relevant consumer choices can be identified and whether data are available to adequately analyze these choices. A point that should be emphasized is that consumer market studies should not stand on their own. They should be augmented with surveys to validate their assumptions. For example, there are several key assumptions used by Blomquist (1979) including the assumption that the disutility of wearing a seat belt is represented in part by the time cost of fastening it. Also, in the case of Ghosh et al. (1975), the key assumption is that the benefits of driving faster can be measured by the savings in driving time. These assumptions can be validated outside the models by using surveys similar to those discussed in Slovic et al. (1977). Too often these critical underlying assumptions remain untested and the policy relevance of the results unknown.

Contingent Market Studies

The contingent market studies performed to date have not used state-of-the-art techniques and the results are subject to a great deal of error. These studies do not demonstrate or adequately test the full potential of this approach for estimating the value of reducing or preventing risks. The most important challenge facing contingent market studies is presentation of the risk choices to survey respondents. More needs to be learned about people's attitudes and behaviors with respect to personal and social risks in order to design survey instruments that communicate the risks meaningfully and adequately elicit the desired information. Due to the paucity of market data concerning risk choices, contingent market techniques may be the more promising, and in some cases, the only available approach for addressing a wide range of issues.

Three general areas of improvement and development need to be pursued in future contingent market studies. These are attention to underlying economic theory, selection of types of risks to be examined, and development of implementation methodology.

Contingent market approaches are based on the economic theory of consumer behavior from which is derived certain expectations about the behavior of rational, utility maximizing individuals. Future studies need to pay attention to the expectations that theory provides about preferences toward safety in order to provide evidence concerning the validity of these expectations. The work of Tversky and Kahneman (1981) provides some alternative predictions of preferences with respect to risk taking that could be considered. Two specific areas that need attention are differences in marginal WTP for safety across individuals and the underlying causes of zero bids and refusals to respond to WTP or WTA survey questions. It could be expected that people who are at higher risk levels would be willing to pay more for a given reduction in risk than people at lower risk levels. This needs to be carefully tested. It is also expected that differences in income and other socioeconomic characteristics will influence WTP for safety. This needs to be routinely examined in any contingent market application. Changes in marginal WTP for safety as safety increases or decreases also need to be examined in order to determine if the demand for safety behaves like more ordinary market goods. Refusal to respond to the questions or zero or very large bids may signal a rejection of the premises of the questions themselves. These kinds of responses need to be probed.

The best contingent market results, in terms of consistency between actual behavior and what an individual predicts his behavior would be, have been obtained when the hypothetical questions relate to

behavior that is familiar and frequently experienced by the individuals. Risks concerning transportation, water quality, sewage treatment, hazardous wastes and availability of emergency services are examples of risks that might be effectively examined. What is most important is that the topic be connected to decisions that people can imagine making.

Two areas that may be fruitful for future contingent market approaches are long latency risks of death, such as cancer, and risks of morbidity. The data constraints that make examination of long-term health effects so difficult in market studies do not constrain contingent market approaches. The link between an exposure and a risk could be hypothesized without having to be proved. Morbidity might be a very good topic for future contingent market studies because it may not face the emotional barriers that the idea of trading money for lives provokes when respondents are asked to consider risks of fatalities.

Many implementation issues need to be addressed in order to develop credible contingent market applications for valuing changes in risks. One of the most important of these is the presentation of the change in risks to be values. Numerical descriptions are probably not good enough. How many people actually know what the numerical risks are for the activities in which they engage? Other kinds of presentations need to be developed that link the risk levels to activities with which the respondent is familiar. All of the bias problems that have been found in previous contingent market applications need to be considered. Differences in the presentation of risk in the bidding or valuation procedure, in the hypothetical payment mechanism, in the order of the questions, and in other information provided to the respondent need to be systematically examined to see if responses are being biased by the survey instrument itself.

Another possibility for contingent market approaches would be to explore indirect valuation procedures such as contingent ranked attributes. In these procedures respondents are asked to rank alternatives without having to put a dollar value directly on risks. Their rankings reveal implicit valuations. Other possibilities would be to ask about willingness to spend time, rather than money, in order to decrease risks.

Other Research Topics

Some evidence has been provided by Litai (1980) and Starr (1969) that different risk types are valued differently. If the effects of these differences in risk types on willingness to pay were known, then the results from a study valuing one type of risk could be used to value other types of risks in environmental benefit studies. For example, at present it is not clear whether wage-risk studies, which reflect the most extensive work done to date on risk-dollar tradeoffs, provide any useful information for environmental policy questions due to the type of risks that were evaluated. Determining the transferability of risk valuation estimates could greatly improve the usefulness of past estimates in policy studies.

The work by Starr (1969) and Litai (1980) provides some initial ideas about how the nature and circumstances of the risk may affect willingness to pay. The Litai (1980) and Starr (1969) studies did not, however, adequately consider the benefits associated with the risks examined. As discussed in Section 5.3, it may be possible to use their data sets, or other similar data, along with better estimates of the benefits of incurring the different risks to obtain risk conversaion factors based on benefit-cost ratios for risks with different characteristics. These could then be used to calculate meaningful risk conversion factors based on the Litai (1980) approach. For example, Starr's use of expenditures on cigarette smoking as the measure of the benefits of cigarette smoking greatly understate actual benefits as measured by consumer surplus. The result is that the benefit-cost ratios he uses to compare voluntary and involuntary risks may be badly biased. In most cases the biases in the benefits estimates seem to create an artificially large difference between voluntary and involuntary risks. The results of an approach that properly account for the benefits would be very informative. Whether the data are available to estimate the benefits of these activities with any accuracy is, however, somewhat uncertain.

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